1995


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USING DRAWING TASKS TO COMMUNICATE IDEAS ABOUT PHOTOSYNTHESIS: A CONCEPTUAL CHANGE STRATEGY FOR USE IN THE ELEMENTARY SCHOOL CLASSROOM

A Dissertation

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

The Department of Curriculum and Instruction

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Abstract

It is difficult for a teacher to determine if a learner has acquired an accurate concept of the topic being taught. Most of the children in this study had sufficient language skills to communicate successfully with their teachers even though they held inappropriate concepts of photosynthesis. This study examined the use of drawing tasks to assess children's ideas related to photosynthesis in an elementary-grade classroom. Two research questions guided the study to determine if this strategy was a valid improvement over traditional methods of classroom instruction. The first question asked if elementary-grade students receiving instruction about photosynthesis would acquire and retain more knowledge when facilitated by teacher-analysis of their drawing tasks than students who received didactic instruction. The second question sought to determine if a fifth-grade teacher guided by students' drawing tasks depicting their concepts of photosynthesis could effect more appropriate conceptual change than a teacher using didactic instruction.

Two fifth grade treatment groups were used in the study. The teacher in the traditional treatment used didactic methods to instruct and evaluate the learner's concepts. The teacher in the experimental treatment used the learner's drawing tasks to communicate and facilitated activities to challenge and change inaccurate concepts. The quantitative results of a pretest, posttest, and delayed posttest were analyzed by ANCOVA with repeated measures to
answer the first question. Clinical interviews, classroom observations, and student artifacts provided data for a qualitative analysis of the second question. These data were examined and analyzed in correspondence with children’s written test responses. Students in the experimental treatment were found to acquire a greater amount of content knowledge than those in the traditional treatment. However, retention of knowledge was not significantly different between the two groups. The teacher in the experimental treatment was determined to facilitate a change to an appropriate concept of photosynthesis in more students than the teacher in the traditional treatment. The experimental treatment was found to provide an accurate depiction of the children’s concepts while the traditional, didactic-style treatment seemed to influence children to conceal their inaccurate concepts of photosynthesis.
Introduction

It’s not difficult to find research today which indicates that the United States’ educational domain is failing to meet the nation’s expectations. Project 2061 (AAAS, 1989) and Project Synthesis (Harms & Yager, 1981), among others, clearly indicate that the United States is not adequately educating many of its students. National Assessment of Educational Progress (1990) reports that only a small percentage of students today possess any significant degree of scientific knowledge. The National Research Council (1982) determined that over 75% of high school graduates were not able to successfully complete a college freshman science course. Not only do the studies emphasize cognitive failures as indicated by students’ lack of content knowledge, there are also clear indications that motivation and affective aspects of learning science have suffered since the 1960’s (Lee & Anderson, 1993; Harms & Yager, 1981).

This evidence indicates that our educational system, especially in science education, does not properly serve our society. With the pace of social, economic, and technological dynamics today, it seems likely that even with the best intentions and drive, today’s students are having a difficult time trying to keep up with the growth in scientific and technological information. Although decreased achievement and less involvement in science classes is not the intent of schools, practices thought to epitomize success in the past functioned well when classrooms were used primarily to provide information
to students. However, the proliferation of information today has reduced past pedagogical strategies to near futile endeavors for students as well as teachers. Doll (1993) suggests that when educational strategies are only designed to increase coverage of material and limit students' success or failure to scores on tests that measure recall of information, the ends are clearly specified and pedagogical means are based upon what will lead to successful test scores. "Such a linear and closed system tends to trivialize the goals of education, limiting them to only that which can be particularized" (p.42). Science education must be as concerned with the interplay of science and society as it is with the facts of science (Simpson & Troust, 1982).

The major goal of science education for the remainder of this century and beyond must be one of promoting scientific literacy for all citizens (Zen, 1990; Simpson, 1983). One response to this has been Project 2061's aggressive campaign to promote a move toward scientific literacy rather than teaching an increased volume of content. While there are several defined and implied meanings of the term science literacy, Sapp (1992) involves two important dimensions when defining science literacy. Both directly address the school classroom. According to Sapp, target areas are "the quality of scientific and technical education that American students receive" and "deficiencies and misconceptions that exist in the overall public understanding of science" (p.21). Literacy implies understanding and many classroom practices today still
measure learning by the volume of content presented to the students. The concern for quality of education becomes significant when we consider that students might not be learning the content prescribed by the schools even though they are taught by seemingly efficient methods. Typically, teaching content to children is considered to be most effective and efficient when dogmatic pedagogy is used. The aged paradigm of "teaching equals learning" is alive and well. The basic problem for the classroom teacher is that words alone don't transmit new meanings (Lorsbach & Tobin, 1992). Each person's prior beliefs and new experiences interact to yield knowledge that is unique to each individual. These spontaneous perceptions of scientific phenomena become an integral part of a person's framework of the world even though they may not correspond to acceptable scientific explanations (Steen, 1991). The basic problem for the learner is that many traditional, efficient classrooms allow the student to maintain inaccurate concepts because these misconceptions are not addressed.

Constructivism Opposes Objectivism

Among the many researchers of children's cognition who have made us aware of and offered descriptions of a constructivist epistemology are Lorsbach and Tobin (1992). They described objectivism, which often informs current classroom practice, as a search for truths which exist outside of the learner. "Knowledge is 'out there,' residing in books, independent of a
thinking being" (p. 9). In such a curriculum framework teachers use a learner’s senses as conduits to objectively transmit knowledge intact into the learner. The assumption is that learners will accommodate to logical and rational information regardless of their prior knowledge. This was the rationale for many earlier (and current) teaching/learning paradigms. Constructivism, on the other hand, asserts that a learner’s senses selectively perceive data which the learner then processes to construct meaning unique to the individual learner. How learners process this perceived data depends upon what they already know and their expectations resulting from this knowledge.

With the current awareness of contrasting epistemologies and impetus from organizations like the American Association for the Advancement of Science, which published Science For All Americans (AAAS, 1989), there would seem to be little doubt that a new pedagogy which promotes constructivist learning principles and literacy would emerge. However, although the authors of Science For All Americans "... recognize that how science is taught is important" (p.145), they only allude to constructivist practices. Their rationale or general purpose for promoting literacy is more evident than their specification of cognitive principles which might help to effect that literacy. A persistent educational mindset of objectivism in many classrooms could make their proposed new curriculum changes ineffective. Shymansky and Kyle (1988, p.324) noted that "...researchers have been able to
discover what should be taking place in science classrooms, but a seeming inability to put knowledge into practice has hindered efforts to improve the process of schooling."

In spite of all the past and current research favoring constructivist pedagogy, practice indicates some curricula and classroom strategies are still based upon a plan that tries to determine the difference between the learner's knowledge and that of an expert and then "fill in the blanks" with the appropriate knowledge (Osborne & Wittrock, 1983).

**Children Bring Ideas Into the Classroom**

Current and consistent findings resulting from research on how children learn indicate that they are active constructors of their own ideas about reality and that these constructions of what their world means to them begins long before they experience the formal classroom. The assumption that children have very little understanding of their world before they enter the classroom or that they will at least ignore their ideas in favor of the logic of a didactic classroom is not valid. Children conceptualize events and objects from life experiences based upon perceptions biased by earlier, and usually limited, experiences. Many concepts related to natural phenomena are shaped to satisfy the frameworks that work well for the child. These spontaneously acquired ideas form the basis of their developing conceptual structures and strongly influence their perception of classroom experiences (Osborne & Freyberg,
They are not isolated ideas. Instead, they provide "... a coherent and sensible understanding of the world from the child's point of view" (Gilbert, Osborne & Fensham, 1982, p. 623). As a result, children's constructed meanings correspond to their immediate, and usually intuitive interpretations. This strategy for interpreting the world and their earlier constructed concepts of phenomena play a part in how they learn science topics in school. Osborne and Wittrock (1983), Driver (1982, 1989), Mintzes, et al., (1984), and many others, found that children usually have some very firm preconceived ideas about the many topics and concepts that are being taught in their science classes. So even though classroom teachers may not be aware of it, classroom knowledge must sometimes compete with children's ideas that were established prior to any lesson and likely differs from a scientific interpretation (Hills, 1989; Watson & Koniczek, 1990). The constructivist-oriented teacher will recognize that children's prior ideas make sense to them and, as a result, will be willing to try to change these children's ideas whenever a discrepancy is indicated.

Rationale for the Study

The notion of classroom knowledge competing with a student's prior ideas seemed obvious when pretests given to the 5th grade subjects of the pilot study for this project were examined. The children's use of terms such as photosynthesis, nutrients, and food, for instance, and their illustrated
understandings of those terms sometimes contradicted each other. One common example was when some children stated that plants made food by the process of photosynthesis yet illustrated that plants used their roots to get food (Illustration 1). Assuming that the information provided to these students in their earlier grades was accurate, the ideas that these children formed about plants were probably influenced from activity outside of the classroom as well as their prior classroom experiences. Their ideas about how plants obtained food seemed to be constructed from what they had experienced related to humans or other animals. The idea of plants actually producing their own food endogenously, as autotrophs, was not being constructed in the classroom. This is a persistent problem in classrooms in spite of the fact that data and materials related to this topic indicate specific differences between the ways animals and plants obtain food. Stavey, Eisen, and Yaakobi (1987) found that most children forgot most of what they learned about plants within one year after classroom study. Information that did not seem analogous to their intuitive understanding of human biology tended to be organized into separate and unrelated mental compartments. Because children’s intuitive understanding of plants can be so problematic, these authors suggested that teachers try to understand the origin of their students’ difficulties.

Conceptual change researchers have noted that children’s classroom activities such as reading, observing, and even some hands-on activities are not
sufficient for teachers to infer what ideas are being constructed. For obvious reasons, it is difficult for a teacher to casually observe students during these activities and then make accurate inferences about what they might be learning. Even though students are eager, seemingly engaged, and apparently delighted, a teacher cannot validly infer that the intended meaning of the activity is being conveyed. This is especially true when hands-on activities are used as adjuncts rather than an integral part of science instruction. It’s difficult to determine how students interpret the intended message of the activity. According to Flick (1993), in addition to manipulating objects and events in a social environment and engaging in a variety of intellectual tasks, teachers need to hold students accountable for their observations, inferences, and conclusions. Student records such as pictures, notes, journals, graphs, and other artifacts should be produced by the students. Teachers can use these to compare what children report verbally and graphically for indications of any contrasts or contradictions. Such accounting might indicate if students are

Illustration 1. There appears to be a contradiction between the child’s text and drawing task depicting photosynthesis.
merely utilizing rhetoric or, perhaps, accommodating some of their misconceived notions to more appropriate concepts. Watson and Konicek (1990) state, "If alternative views of scientific principles are not addressed, they can conflict with 'what the teacher told us' and create a mishmash of fact and fiction" (p. 681).

Teachers of children face two basic problems when trying to teach concepts and principals related to natural phenomena. When children have prior knowledge of the phenomena, there is a tendency for them to try to assimilate only the data presented that corresponds to their existing ideas. When the phenomena are unfamiliar to the children, they try to assimilate the new data into existing frameworks that seem to them to be reasonably analogous whether accurate or not. One way that children learn is through the assimilation of new information into their existing models or schemata that seems analogous to the new information (Duit, 1991; Dupin & Joshua, 1989). So it helps when the new knowledge has some physical counterpart in their experiences. Photosynthesis is one scientific phenomenon that does not. One problem that science teachers have with teaching photosynthesis, for instance, is that they can't provide a reasonable analogy for this process. There is not much analogous to the use of air and water to make food inside of an organism. So, it is hard to put such a new idea into concrete form. Usually, children use some anthropomorphic view which is familiar to them in order to
link new experiences and information (Wandersee, 1986a). When children are faced with the idea that plants need food, they are likely to use a human or other animal analogy. They relate the new to something familiar. Their own model of how plants get food is what all others are compared to and they actively learn on the basis of what they already know. Because of this, children try to "... propose some relevant hypothesis and keep some structural isomorphism" (Dreyfus, et al., 1990, p. 210).

In cases such as this, it would seem appropriate to take advantage of how children learn. They will try to conceptualize through natural experiences and form an analogous model to predict from. Dreyfus seems to think that what we see as stubbornness in children may be their intellectual integrity resisting changes in whole conceptual frameworks. Rather than admit they are unable to change a whole framework, children resist change. According to Dreyfus, et al. (1990), in order for children to learn a new concept or change an existing one, these children must be actively involved in the process of reshaping and restructuring their current ideas. The starting point of this process should be their naive knowledge. This project attempted to help both teachers and children become aware of the children's ideas about plants and actively engage in a learning process that encouraged children to accommodate their existing ideas about plants to a more scientifically acceptable one.
It seemed that it would be helpful for a teacher to actually see the children’s models of plants and challenge them when necessary. One strategy was to provide quasi-natural experiences with contrived situations designed to test children’s models of plants getting food. If a teacher could see a child’s analogy of how plants "eat", he or she might be able to facilitate a change to a more accurate model without the risk of the child perceiving the new model to be unrelated to his or her present one. One major problem with misconceptions about topics is that they hinder the development of new ideas because the wrong new links might be made. Newly perceived data are likely to be assimilated so that it will conform to current models in a learner’s long-term memory (Osborne & Wittrock, 1983). When the superordinate concept within a framework is not appropriate to the new data assimilated, other concepts within the framework influence the development of an inaccurate concept (Eaton, Anderson, & Smith, 1983). Because of this, it is important that teachers be able to see the links being made between the new data and the children’s prior knowledge.

One major impediment to the constructive learning process of children is that some classrooms use a common pedagogical strategy of "filling in the gaps" or providing information for rote memorization to correct children’s misconceptions. Children tend to compartmentalize such data when they fail to understand it (Stavey, et al., 1987). This is especially true when they feel
the data are going to be needed in the classroom again. They do this even though they can’t incorporate the data into any of the cognitive models they normally use to explain and predict everyday phenomena. They do, however, have links to the compartmentalized data. They can usually translate the data into classroom jargon and then incorporate this into discussions and events in classroom settings. They learn to apply the proper terminology to the proper classroom scenario. This makes it difficult for a teacher to discern correct conceptual construction from verbal analysis alone. However, Silver (1981) suggested that when children construct visual models by drawing tasks, it may be more representative of their real ideas than their language indicates. Further, any contrast between verbal and oral expressions related to a concept and a child’s graphic representation of the same concept should be obvious to the teacher. Barlex and Carre (1985) suggest that children’s illustrations are probably the best indicators of how they conceptualize something.

This project examined the contrast in children’s ideas about plants when they expressed these ideas in a verbal mode and by drawing tasks. The role of sunlight in plant nutrition is one common example of such compartmentalized data. Children know that it is associated with a plant’s food, but they don’t seem to know quite how it is associated (Illustration 2). Light energy is not usually a part of any of their models yet. In spite of this, they can interject the term light (because it has been said to be appropriate with plant growth)
and even the term photosynthesis to supplement their various models of plants whenever it is necessary to engage in textbook-style conversations (see Illustration 1). Such semantic maneuvering enables them to discuss the role of sunlight in photosynthesis without revealing or otherwise disturbing their realistic model of how living things obtain food; that all living things ingest food from a source external to their structures. However, their drawing tasks produce illustrations that seem to reveal another meaning to their words.

Research Questions

As children gain social experience, some become quite adept at word maneuvering. They can skillfully interject semantic intentions to explain phenomena even when they have no idea of the related extensional referent. This seems to be exemplified by the child’s verbal explanation of photosynthesis in Illustration 1, and the other child’s use of the term light in Illustration 2, to somehow make classroom discourse more palatable. Children are sometimes able to erect a verbal facade to disguise their conceptual models whenever these might not conform to the real conceptual referent or denotation.
of an object or phenomenon. The above illustrations taken from the pilot study for this project seem to suggest that the models illustrated by children to depict their conceptual referent are more indicative of their cognitive models than their written description. This project contends that illustrations used by children to represent their ideas can be used to communicate with a teacher who intends to facilitate appropriate challenges and other activities in order to meaningfully alter some of the children's ideas which are found to be misconceptions. The intent of this project was to answer the following research questions:

1. Do elementary-grades students receiving instruction about photosynthesis acquire and retain more knowledge when facilitated by teacher-analysis of their drawing tasks than students who receive didactic instruction?

2. Can an elementary-grades teacher guided by students' drawing tasks depicting their concepts of photosynthesis effect more appropriate conceptual change than a teacher using didactic instruction?

Definition of Terms

For the purposes of this study, the following terms were defined:

- alternative conceptions - see misconceptions.
- concepts - a general notion or idea formed about something when all of its characteristics or particulars are considered. Also, a label given to the identifiable regularity in characteristics or particulars about something.
denotation or conceptual referent - the things or objects to which a word applies.

extensional referent - denotation.

intentions - the associations a word has in the mind of its user.

misconceptions - propositional knowledge constructed by individuals that is considered contrary to scientific knowledge and that might interfere with the learning of scientifically accurate knowledge.

semantics - pertaining to the different meanings of words.

semantic facade - the rhetorical use of a word when it is different from the user's conceptual understanding.

semantic maneuvering or manipulation - using words in a particular context to intentionally direct the perception of a listener.
Literature Review

According to Simon (1985), we sometimes mistakenly believe that our language represents the reality of our world to everyone. This presents an exceptional challenge for teachers of young children. Children’s links are rather limited, their models are somewhat unsophisticated, and they seem to have no problem with simultaneously held ideas that logically conflict (Roth & Anderson, 1987). Learning biological concepts in a classroom environment, especially photosynthesis, can be especially problematic for children who don’t have the schema to restructure conceptual frameworks beyond what their intuition enables them to (Anderson, Sheldon, & Dubay, 1990). A child’s model of a plant is, in many ways analogous to animals. Such schema induces inaccurate conceptions about photosynthesis (Carey, 1985). The children can participate in classroom dialogue because many of the terms such as food, energy conform to familiar English usage and compatible classroom discourse can occur even when concepts related to these terms differ between child and teacher. Because of this, it might be difficult for a teacher to determine the real nature of children’s concepts.

Classroom teachers should be aware that the words they use to represent concepts do not always represent some specific reality that can be learned by children (Lorsbach & Tobin, 1992). This is especially true about photosynthesis. Most children have no schema that can accommodate to this
term. A child's perception of object is mostly experiential with many links to
They can usually assimilate ideas about food and energy for plants into a
model for plants because it seems analogous to their real-life experiences with
animals. This becomes especially difficult for the teacher because this places
a higher value upon the child's prior knowledge and increases the difficulty of
ever changing their misconceptions about plants (Barker & Carr, 1988).
Anderson, et al. (1990) noted the similarity in responses about photosynthesis
between children and adults indicating that misconceptions about plants are
very resistant to tuition. This is a problem since an understanding of
photosynthesis is believed to be a prerequisite for any systematic
understanding of ecology.

While a student's prior knowledge about certain topics should actually
be appreciated by teachers, ethnographic studies conducted by Tasker (1981)
indicate that teachers often presume that children come to class with specific
prior knowledge or that they have no knowledge that would interfere with
specific lessons. However, because of children's prior ideas, what they
understand in class may not be what the teacher assumed would be
understood. Darnier (Thijs, 1992, p.156) noted, "Teaching is not the
transmission of knowledge but the negotiation of meaning. It involves the
organization of situations in the classroom and the control of tasks in a way
which promotes intended learning outcomes."

According to Novak (Wandersee, 1986b, p. 415), "A child is ready for meaningful learning in a subject area when he/she has some specific, relevant subsuming concepts". There were indications that the children who participated in the pilot study for this project came to class with prior knowledge about plants. They were ready to subsume some of the data proposed in the classroom into their preexisting concepts related to plants. They were not, however, ready to change their basic ideas about how plants obtain food. Illustration 3 suggests that this child was aware that light and/or energy had something to do with food for the plant. In spite of this, the illustration suggests that the plant still used its roots to get food from the soil and energy from water. The child could obviously utilize some of the terminology generated in class, but was unable to use it appropriately. The meanings of these new terms probably didn’t correspond
to any of the child’s real ideas about plant nutrition. One reason children
might develop such misconceptions about photosynthesis or the autotrophic
characteristics about plants was elucidated by Wandersee (1986b, p. 423)
when he stated, "... students commonly anthropomorphize their concepts
and therefore perceive animals as relating more directly to their own
experiences. Humans, as heterotrophs, have great difficulty imagining what it
would be like to be a plant and to live without eating". Moreover,
photosynthesis is indeed an abstract concept that we cannot sense occurring.
A child might never have the opportunity to have a spontaneous, concrete
experience with photosynthesis. This makes it difficult for children to
construct an accurate concept of photosynthesis. Some of children’s ideas,
which seem to persist even into adulthood, can be identified from statements
such as, "plants eat dirt, plants get energy from water and minerals,
photosynthesis is a growth process, chlorophyll is a plant food, we can feed
plants with fertilizer, and plants breathe carbon dioxide and exhale oxygen"
(Wandersee, 1983; Mintzes, et al., 1984; Mintzes & Arnaudin, 1984; Roth &
Anderson, 1987; Anderson, Sheldon, & Dubay, 1990; Shymansky & Kyle,
1989). Such concepts of plants are maintained even by some science teachers.
Some children are able to speak the appropriate language even though it
conflicts with their model of plants (Stavey, et al., 1987).
Conceptual Change Theories

The first step toward preventing children's established ideas from interfering with what is being taught in the classroom is to become aware of what these ideas are (Duschl, 1991). A child's concepts may not be portrayed by the words they use to express them. Yet, these concepts represent the framework that the child uses to assimilate or otherwise accept what is being presented in class. Regardless of the intention of the teacher's presentation, it is common for children to selectively accept only what is needed to support the integrity of their conceptual ecology, valid or otherwise (Barker & Carr, 1988, and Stavey, et al., 1987). Children interpret scientific phenomena to fit their experience and point of view rather than the scientific point of view (Vosniadou, 1988; Gabel, 1994). The subtle irony is that teachers usually attempt to offer children a logical, simplistic, linear presentation with the expectation that a child's complex model will accommodate to it (Doll, 1993). The reality, though, is that the complexity of the links that formed the children's model will only allow fragments of a teacher's presentations to be perceived and assimilated into their model. They are looking for the right pieces and teachers may be offering logical chains. Whenever necessary, children can easily separate the school science from their perceived reality.

Children use ideas generated from constructed concepts to make sense of and to predict events in their environment (Lorsbach & Tobin, 1992).
These children's ideas are enmeshed in very complex conceptual structures that give them their sensible understanding of the world. However, it is easy for them to maintain several contradictory ideas about any one particular topic. Normally, when late adolescents or adults reflect on these contradictions, they might become aware of some of these discrepant ideas and recognize a need to reconsider their current ideas. However, Hills (1989) says that children have a tendency to apply their reasoning to specific events rather than to broad comprehensive generalizations which would require them to compare their whole framework to new ideas. For example, a child might assume that houseplants must be fed by plant food even though the same plant in the yard can eat dirt. However, if this plant is being rooted in water, the child might state that the plant uses sunlight and water to make food.

Teachers of children who still maintain some of the traits Piaget identified as pre-operational and early concrete-operational have special problems in the classroom. Some of these children might not be able to generalize broad characteristics of a whole class of plants to what they see as separate organisms rather than subclasses of the general plant model. They might center on the superficial characteristics of specific plants that are in specific environments and be unable to classify them to the general plant model (Carin & Sund, 1989). However, for children of the general age of
fifth-grade students, the task can be outlined. These children might be able to be influenced by an awareness of contradictions to their points of view.

The non-reversible thought of children with preoperational traits contrasts with the reversible thinking or operational thought processes available to some fifth-graders. When dealing with certain phenomena, they are more likely able to consider real objects in their environment in terms of classes rather than isolated objects. This development of the intellect toward a more logical way of processing data results from what Piaget described as a process of equilibration or self-regulation (Trojack, 1979). Doll (1993) illustrates this process in a context of activity that seems closely related to the elementary school child. "The learner's structures, as they interact with the environment, first simple assimilations and accommodations but eventually--at a nonpredictable threshold or bifurcation point--combine to make a sweeping change . . . transforming themselves into new and more sophisticated structures" (p.71). As the child spontaneously experiences the environment, data are assimilated with corresponding, but unpredictable, changes to his/her conceptual frameworks. Eventually, a continued correspondence between the child and the environment reaches the point where what once were isolated structures begin to logically merge into new classes of objects or situations that help the learner solve sensed problems or make things fit better in the environment (Siegel, 1984). This accommodation of the learner to the
environment is a self-regulated process where the child is actively involved and self-directed in the process of reconstructing schema to fit his/her own conceptual frameworks. There are points in the development of conceptual frameworks where significant associations or links that were not possible earlier are now possible and reasonable to the child even if they might be scientifically inaccurate.

Although children’s perceptions become more selective as they mature, they can broaden their conceptual scope as frameworks become more defined. For example, as plants are found to be classified under the superordinate concept of living things and are perceived as such, they can be perceived as likely doing all the things that other living structures, such as humans and other animals, do. The child must do this to broaden his or her perception of the environment and, at the same time, categorize objects and events to restrict the scale of the total domain. Even though children are capable of constructing conceptual frameworks that enable them to function with increasing degrees of effectiveness within their environment, there are no structures that suggest a perception standardized to all children. This means that each child responds to the environment in a unique, self-regulated process (Piaget, 1950). As Doll (1993) put it, the child must actively respond to the environment yet resist any tendency to change. The tendency to resist indicates the willed purpose of the child. The nature of each child to deduce a
unique construction is based upon past experiences. They shape themselves only as they interact with the environment. The classroom teacher must be aware of this.

Piaget's early constructivist implications indicated that knowledge is constructed in the minds of children through their actions such as the logical mathematical activity of classification. Although children around the age of fifth-graders can usually engage in logical mathematical thought, Piaget believed many of the children of this age were still under some influence of early reasoning strategies that he described as pre-causal (Good, Mellon, & Kromhout, 1978). This makes it easy for them to link events together in an uncritical way without any consideration of other's points of view. Because of this, even though children can be brought to understand some generalizations related to plants under different conditions, it is not uncommon for them to fail to recognize that they may have classified one plant under three different nourishment schemes. Bringing these contradictions to the attention of a child is not usually sufficient motivation for the child to restructure his/her conceptual framework (Gabel, 1994). Some children may not be willing or even able to reclassify isolated concepts so that they generalize to one framework (Hall, 1989).

A significant consideration for any conceptual change strategy in classroom activities is that children probably won't respond to slight or
occasional perturbations. The disequilibrium must be deep-felt and sensed as real. The activity must enable the child to restructure something into a model that will enhance their existing conceptual frameworks or satisfy what was a conceptual problem. If the child experiences fragments or isolated bits of data, there will probably not be enough structure to cause the child to sense a conflict between what they know and what they perceive the environment to represent. They must feel the need to engage in cognitive activity that searches for links between existing ideas and perception. "The physical world must be left and the logical and abstract must be taken on instead" (Doll, 1993, p. 80). Posner's theory of conceptual change (Posner, Strike, Hewson, & Gertzog, 1982) states that the beginnings of changes in one's conceptual ecology will result only when a conflict between a learner's current models and new perceptions, which are related to these models, imply a competing concept which appears to be sensible and plausible. Before learners can accommodate their existing ideas to the new, contrasting concept, they must recognize and accept that unless something is changed, their current ideas will probably result in a number of unsolved problems relative to the present framework. New perceptions of phenomena no longer fit their old framework. Even with this, though, the new idea must be able to replace the old one, solve problems, and still fit with other concepts within one's framework related to the phenomena discussed. Also, the new idea must be
intelligible such that one can see how it may be of use based upon past or current experiences. Even if the new concept or theory does seem intelligible, it cannot be counterintuitive. It must fit into the learner's conceptual ecology in ways that can create new images and still fit one's fundamental beliefs about the world. According to Posner, et al. (1982), conceptual change occurs against current concepts or the paradigms that a person uses to "define problems, indicate strategies for dealing with them, and specify criteria for what counts as solutions" (p. 212). Because of this, children tend to perceive experiences in ways that will reinforce their existing models. Although they will react to anything that would indicate a challenge to their conceptual models, the tendency is to assimilate only that which might link to their past experiences and rationalize their existing conceptual models. So, although new experiences can alter conceptual models somewhat, the concepts basic function within the framework tends to remain intact unless some radical events occur (Gabel, 1994). But, as Posner, et al. suggests, even when one is faced with considerable anomalies due to perceptions conflicting with one's concepts, sufficient perturbations to initiate conceptual change might still be averted. When faced with these anomalies, there are still three more basic responses possible from the learner. They can (1) reject what seems to be apparent and provide their own theory to assimilate the data, (2) compartmentalize the new data to avoid the conflict with their existing beliefs,
or (3) force assimilation of the new data into their existing conceptions (Posner, et al., 1982). Most children seem to do at least one, but might even manage a combination of these three alternatives. When children have less than formal reasoning strategies, the spontaneous aspect of their learning by the assimilation of data perceived under the influence of their past experiences does not lend itself to logical, and sometimes rational, conceptual change. Teachers who are unaware of what is influencing the cognitive processes of the child face a very difficult challenge when they are expecting conceptual change in a classroom.

**Generative Learning**

Osborne and Wittrock’s (1983) Generative Learning Model lies within the constructivist tradition and postulates that learning is an outcome of an interaction between prior knowledge and sensed information (Barker & Carr, 1988). This model illustrates the process in which learners compare perceived sensory data to what they consider to be a relevant model in their long term memory. This process of comparison is where the learner assimilates the salient characteristics of the perceived object or event into his/her preexisting cognitive structures that serve as a template. Any new data which do not fit the learner’s existing schema or model might be selectively ignored. That which is considered sensible might be added to the learner’s repertoire of knowledge. Generating links means forming relationships with other
conceptual structures and also prioritizing the new data within the established hierarchy of a relevant conceptual framework. According to Barker and Carr (1988), learning is the generation of links between sensed information and prior knowledge. After some consideration of how this new information affects prior links, the meaning of the new data are accepted or rejected. This is where the learner actually begins to construct meaning from perceptual experiences.

During this cognitive process, constructed classroom meanings could vary a great deal from what a teacher may have intended. Variance depends, to a great extent, upon the individual learner's prior experiences. Assuming that enough short term memory is available to the learner, new links to certain structures in the long term memory might be stimulated and, as a result, substantiate some of the new features perceived by the learner. This might help the learner form a newly perceived tentative model in the short term memory. These new links between newly perceived data and the learner's prior knowledge might continue until the new model "fits as is" or the learner selectively assimilates only that which comfortably fits what is already known. In such cases, no significant new learning occurs.

According to Osborne and Wittrock, generative learning suggests that while the tentative model is being considered in the short term memory, the learner continues to re-test this new model against the sensed data until the
final understanding or the "fits as is" process is complete. If the learner’s re-
check against the newly sensed data goes unchallenged, the selective
perception or assimilation of the object or event’s characteristics is not likely
to produce a new model which is radically different from what exists in the
accepting framework. This is because the learner’s pre-existing frameworks
satisfy expectations sufficient to bias perception (Hills, 1989). Because of
this, teachers need to become aware of the child’s developing model and
provide the challenge, when needed, to the perceptions that the child’s prior
ideas might be supporting.

In order for accommodation to occur, the learner’s view of how
something works and its relationship to existing concepts must undergo some
fundamental change (Kyle & Shymansky, 1989; Dykstra, et al, 1992). The
characteristics of an object or event which were constrained by earlier
selective perception now become obvious and relevant. Should this occur,
some previously observed object or event will have new meaning and this will
ultimately influence all prior links. The learner’s world view will have
changed. This suggests that the learner’s initial tentative model in the short
term memory might have been challenged during a re-test against the sensed
data that was being assimilated (Osborne & Wittrock, 1983). Such a
challenge makes the learner less likely to reasonably ignore any data that
didn’t seem to initially fit the tentative model being held. This is a key point
of intervention by the teacher. The learner's model might be altered at this point such that it might enable the assimilation of the data previously ignored. However, even though some conceptual change does occur, accommodation does not necessarily mean the new concepts agree with experts.

The Role of the Classroom

In many classrooms, pedagogy depends upon the management of students so that knowledge can be transmitted from teacher to learner via words. But, learners seem to function best in an environment that allows them to process information in a manner compatible with their cognitive system (Black, 1984). According to Maturana's theory of structural determinism (Efran & Lukens, 1985), we can't change organisms. We have to "...design an environment for the organism to thrive, respond, and change itself" (p. 23). However, many elementary school science classrooms still depend upon objectivist strategies to teach to token cooperative groups who are using hands-on activities while they follow recipe-type directions. Contemporary pedagogical tactics designed to function within a constructivist framework are not very effective in an objectivist-style classroom. Harlan and Osborne (1985) seemed to be addressing this when they stated that elementary school science lacks "...consistency between aims and implementation."

Classroom strategies for teaching science should be compatible with how children learn and the prior knowledge they bring with them. Our model for
teaching must be "...explicit about what our view of learning is" (Harlan & Osborne, 1985, p. 138).

Teachers improve the chance of changing children's ideas when they directly address what might be a child's misconceptions (Roth & Anderson, 1987). A teacher's tendency to guide a child to just say the right things usually only seduces the teacher into thinking the child has a new meaning. However, new meanings represent a change in the complex relationships of the concepts in a child's framework and the meanings of the words used to represent these concepts (Stenhouse, 1986). If a teacher can actually see what a child's words mean, the teacher might gain new insight into what the child really perceives. However, if teachers expect to influence children's perceptions, they need to make every effort to attend to what children observe, their explanations of what is occurring, and the predictions a child makes (Glasson, 1989).

The problem some teachers have with trying to verbally provide intact ideas to children to "fill in the blanks" is that these teacher-selected scenarios which should logically reorganize a child's misconceptions are treated by children as they would treat any other spontaneously generated data. These contrived scenarios or presented data can be very selectively perceived by children and assimilated such that it will not interfere with their overall schemata. According to the Generative Learning Model (Osborne &
Wittrock, 1983, p. 493), when data do come in, "... we must invent a model or explanation for it that makes sense to us, that fits our logic, or real world experiences. People retrieve information from long term memory and use their information processing strategies to generate meaning from the incoming information, to organize it, to code it, and to store it in long term memory."
The point being made here is that the data deemed necessary by a teacher to make the link for an appropriate conception might not be perceived intact by the child. It might be perceptibly altered to fit the already existing models which are in the child's long term memory. Semantic facades such as "the sun providing energy for a plant's food" (Illustration 4) can be erected by a child to strategically provide appropriate feedback to the teacher. What teachers need to do is enable children to show us their model or how they really think when they refer to certain ideas (Owsley, 1989).

Maturana (1987, p. 67) stated that, "All scientific explanations, whether to oneself or to others, contain a description of a mechanism first and then predictability as a result of the mechanism". This seems to say, as Osborne and Wittrock (1983) summarized that learners try to make links between a perceived phenomenon and their long term memory to produce a model that enables them to understand and predict the outcome of the phenomenon or event. According to Marx and Toth (1981, p. 390), "We have a neurological system that processes incoming stimuli with anticipation that it will fit our
mental model." We try to make predictions about our environment which, if fulfilled, will enable us to use our model to represent reality as we perceive it. We can compare Maturana's mechanism to the short term memory's temporary mental model of perceived phenomena or events. When the mechanism, or model, is no longer able to provide predictable results which satisfy a particular phenomenon, there is no longer a scientific explanation. The learner must then alter the current mechanism or invent a new mechanism to explain the phenomenon. Each change in the mechanism is a response to a learner's proposition or hypothesis and represents changes in his or her concept of the phenomenon. So, these are choices the learner can make. Depending upon the structure of the conceptual framework the target concept is part of, the learner's past experiences, and the perceived need to effect changes, it is not likely that one experience will settle the conflict, much less provide an appropriate change. If a teacher expects to intervene at any point in order to appropriately guide
the changes, a child’s changing model must be apparent to the teacher (Ahlgren, 1993).

Using Drawing Tasks to Communicate

Within the framework of a constructivist epistemology, a teacher should always be aware of what children know about the topic under study and the things that the children consider closely related to this topic. This could help the teacher facilitate the changes necessary to satisfy an orthodox model (Searle & Gunstone, 1990). The key to this strategy is to know where the child is relative to the considered topic. But, as discussed earlier, a teacher who depends solely upon semantic feedback from the children to illustrate their concepts may have problems because many of the real ideas that children have constructed to explain their world are done so intuitively and without language (Osborne & Freyberg, 1983 and Lorsbach & Tobin, 1992). When children do learn the words they can use to relate their ideas and models to others, the semantics may not correspond to an orthodox referent. The label they are using to communicate with might not identify things as they are perceived by others. A problem with teaching children is that their perceptions occur behind closed doors and are not usually subject to a teacher’s scrutiny. What the learner is constructing from the teacher’s data for subsumption into long term memory is under the influence of prior knowledge and can easily go unchecked (Shuell, 1987). When the learner
does sense an obvious difference between his/her ideas about a topic and the classroom meaning, a dichotomy can sometimes exist rather than an exclusion of one or the other ideas. The classroom concept can be compartmentalized exclusively for use at school while the real life ideas might remain unchanged. Some learners can skillfully paraphrase or even synthesize school-use knowledge with what they consider to be their appropriate ideas. They can do this in ways that deceptively indicate a certain degree of mental processing.

Silver (1981) noted that when some children's operational knowledge about something is not functional, they can still simulate literacy related to the topic by using key rhetorical phrases. They compensate with words that might lure the teacher to assume a compatible link between what the teacher and student think.

Curtis (1988) noticed that when students were required to describe as well as analyze specific issues by graphic illustrations (such as would be the functional aspects of photosynthesis), specific anomalies seemed to stand out from the totality of the visual statement even though they were not evident in dialogue. These discrepancies can be very useful for a teacher to use for a visual analysis of a child's concept that is illustrated by drawing tasks. The drawing task can be used as a procedure to help the teacher see the dichotomy between a child's proclaimed facts and his/her real ideas. Children's cognitive skills are very evident in both visual and verbal modes (Howe & Vasu, 1987;
They can construct models to represent their experiences even though their language may be limited or even erroneous (Silver, 1981). Barlex and Carre (1985) explained that whether one is drawing or analyzing a picture, something is created internally which complements what is visually perceived. The picture links with what is already known. These links become obvious when the child's model is illustrated by drawing tasks. An observer might be able to see some signs of how the conceptual links are generated by the illustrator.

Observations that children make are influenced by their prior experiences and, as a result, are going to be encoded and linked in intuitive ways, often encoded without words. "We do not see things as they are, we see them as we are" (Barlex & Carre, p. 4). The child in Illustration 5, for example, seems to know that a plant's roots, the soil, and its nourishment are closely related. However, it seems that the photosynthetic process involving light and the plant making food inside of itself is being made to fit even though photosynthesis seems to be misunderstood. In spite of this, the child can probably provide an oral explanation that light, water, and nutrients are becoming food. As a result, a teacher might incorrectly infer meaningful learning by this child.

In spite of their explanations, children usually lack the logic to fill in the gaps between what they propose to be correct and what would seem to be
so upon careful analysis (Shapiro, 1989; Hills, 1989). Negotiations between a child and the teacher which focus upon graphic models illustrated by the child's drawing task might be able to help the teacher follow the child's reasoning. Symington, Boundy, Radford, & Walton (1981) focused on the implications that resulted when children shared their observations of natural phenomena with a teacher. Verbal and visual communication with the teacher helped to illustrate the way the phenomena were encoded by the children. Their conceptual links became apparent when the children only had to explain things by drawing tasks rather than by using terms that undoubtedly had ambiguous meanings to them. Most of these children's drawings seemed to represent a stage described by Bird and Diamond (1975) as visual symbolism where the picture depicts a symbol of a child's ideas rather than visual realism. Visual realism is thought to demand too much confusing detail for children. They must try to incorporate too many well-placed words to match the tedious detail they perceive as proper science. However, when
carefully done, they can usually depict with accuracy what it is they do understand (Dwyer, 1978, 1988). Symbolism seems to be closely related to what Barrett and Light (1976) referred to as intellectual realism. This is where a child might draw "what he knows and not what he sees" (p. 198).

In teaching or guiding children to produce communicative drawing tasks, there are some definite guidelines to follow. Drawings with too much detail, such as labeling too many structures on a picture—a tendency for a zealous teacher—might interfere with student learning (Moncado & Wandersee, 1993; Dwyer, 1978, 1988). Common line drawing is suggested since it seems to represent ideas rather than striving for realism which might be overwhelming or, at least, distracting.

One of the main problems in science classrooms is that detailed illustrations are used to teach the structure of biological organisms while ignoring their function or whether or not the child understands how it works (Ost, 1987). A child’s model illustrated by drawing tasks can serve as the medium that he/she can use to locate and identify the interrelated components that help to describe the function of the object or phenomenon being studied (Wandersee, 1981). The drawing task’s illustrations can help to make the effect of these functional variables more obvious to the teacher and student. Much about a child’s understanding of the biology of a plant, for instance, can
be recognized when any combination of light, water, root media, and other variables are manipulated and the predicted outcome of the plant is represented by changes in a graphically illustrated model. This is because the perceived results of the interaction of the variables become a part of the model (Ost, 1987). The child is able to state the effect of the changes in these variables as hypotheses and use the model as a means of predicting and gathering data about how the model works. A teacher, in this case, can view these visually illustrated statements and might possibly perceive how it fits within a conceptual framework. In each of the previous illustrations, a child was explaining how changes in certain environmental variables were affecting their plant models. These visual models provided the teacher with insight into the child's mental model.

As the data change and a learner's ideas change, his/her cognitive models change and the conceptual links representing interrelationships change. Analysis of these models might help a teacher guide students toward a scientifically acceptable model of a plant. This analysis is described by Curtis (1988) as a form of deconstruction (used literally rather than in a postmodernist literary sense) or taking apart what the child has constructed to examine its components and the principles involved in this construction in order to discern some of the relationships involved in his/her conceptual framework. If a plant does get food intact from the soil, for instance, what is
the purpose of the sun? This taking apart begins, however, with a careful acknowledgment of the intact illustration. Dwyer (1988) suggests that teachers should encourage the elimination of superfluous data, such as excessive detail, that might make analysis difficult. To prevent any misleading assumptions, Curtis suggests arrows, simple lines and indicators with some slight verbal explanations to ease the proliferation of graphics and to merge verbal and visual thinking.

Without language, or terminology, as the primary source of dialogue, children are deprived of a major tool to disguise their misconceptions. Their drawing tasks produce illustrations which "can represent their reality vicariously and economically, and thus reflect their thinking" (Silver, 1981, p. 4). Because of this, teachers might be able to find out what a child's definition is, see how it works and the meanings it has in the context it was intended for. Changing children's points of view is a gradual thing because what they already know has a strong influence on what is presented to them and any changes must be reflected in their whole conceptual framework (Brown & Clement, 1989; Vosnoud, 1989; Demastes, 1994). They should be given a chance to make use of the similarities and differences between their existing models and any of the proposed contrasting models to organize their ideas. For example, children usually only maintain some intuitive rationale to support a plant's need for sunlight. Proposing the idea of plants without
sunlight might provoke some reconsideration of the validity of their responses to an extraordinary interaction between a plant and light.

**Conceptual Change Research**

Eaton, Anderson, and Smith (1983) tried to induce change in children's misconceptions about light. They felt that a major flaw in their procedure was not directly addressing the children's misconceptions. As a result, the instructional data provided to the children didn't make sense to them because they could not associate the data with their naive preconceived ideas. The researchers insist that being able to make the correct links from perceived data to preconceived ideas and models is critical. These links determine the associations we make between the new ideas and prior knowledge. If teachers unwittingly entertain a child's misconception, "... every new term or theory will be integrated into that faulty conceptual framework" (Eaton, et al., p. 25). Because of this, teachers must know what the children know as well as what they don't know.

Smith (1983) had experiences which were similar to the former team. He also gained further evidence that children's preconceptions will usually persist even though they are provided with theories which contradict them. He insists that providing logical presentations as though children have no preconceptions is not effective. Providing logic alone is not a basis for children's accommodation because there are prior conceptions which need to
be addressed. Instruction which only provides data, though logically presented, usually fails to enhance future learning when the nature of related concepts constrain appropriate meanings intended by the instruction.

Nussbaum and Novick (1982) estimated only 20% success when trying to change children’s ideas to accept that light is the only source of energy for the food plants use. Their strategy did involve exposing children’s misconceptions and making them aware of these misconceptions. This was followed by the use of a discrepant event to produce the necessary conceptual conflict. Their intent was to guide the children to accommodate to an orthodox model. They said that their fundamental error was in assuming that a major, abrupt change in children’s concepts would occur instead of realizing that these changes usually occur in increments. They think that greater success would have been possible had the children been able to test their individual misconceptions rather than using strategies which assume one or more generic misconceptions. Their recommendation was to match instruction to each child’s conceptual ecology.

Roth and Anderson (1987) looked for a teaching strategy that would help middle school science teachers promote meaningful conceptual change about plants. They concluded that they failed to recognize that the children did not have a proper concept of food being a source of chemical energy for
an organism. The children's skillful use of semantics for the referent food was deceiving. Their concept of food did not provide a proper framework to assimilate the idea of what was significant about sunlight as a source of energy. They also decided that too much data and detail were involved.
Materials and Methods

Pilot Study

The pilot study for this project was conducted at an elementary school located in the northern periphery of the city of Baton Rouge. It focused on indications that children in elementary grade science classrooms used terminology during classroom discourse that appeared to be quite different in meaning from the teacher’s. School children seem to develop expertise in semantic manipulations that enable them to skillfully utilize particular terms in the context of a classroom lesson in order to disguise their lack of understanding of these terms (Brown & Clement, 1989). As a result of this, teachers and children may be using a common conceptual label even though they are not referencing the same concept. If children perceive the teacher’s referent to a particular conceptual label such as photosynthesis to be quite different from their own, they might develop a strategy that enables them to compartmentalize rhetorical discourse that will appease a teacher. A child’s conception of how plants obtain food is supported by the child’s conceptual framework of which it is a component. Compartmentalized discourse structured by rhetorical links seems easier for the child than their task of trying to restructure the links in a conceptual framework that includes their understanding of photosynthesis. The researcher’s task was to find a medium
of communication that would illustrate a child’s concept of photosynthesis without a rhetorical facade.

The scheme was to have a group of fifth-grade students engage in drawing tasks to produce an illustrated, working model of how they believed plants obtain food in a specific environment. They would then predict the outcome of a real plant in the same environment based upon it corresponding to their represented model. Each episode of plant behavior that the children participated in represented a new environment which would affect the life processes of their plants. Each time the students’ models did not accurately represent the outcome of the real plant, they were encouraged to change their model over the course of a series of experiences with real plants that were subjected to the same variable manipulation as their hypothetical model was subjected to. The purpose was to compare their intensional referent, or the associations a word has in the mind of its user, to the extension of the concept or how they actually perceived that plants obtain food (Sartori, 1984).

To initiate the activities, each child was provided with potted bean plants in the early true leaf stage. They were to observe their plant in situations where the light, root media, and liquid supplements were varied. The next step tested their hypotheses, or predictions, against the actual outcome of the plants. All data were recorded by drawing tasks used to construct the illustrated models of the plants representing the children’s
predicted outcome, by annotations and captions for the illustrations provided, and by journal entries. Structuring the children’s responses in this fashion made the differences between their predictions and the actual outcomes immediately visible to the children and to the teacher (Sigel, 1984; Copple, Sigel, & Saunders, 1984; Sigel & Cocking, 1977). The illustrations were expected to visually depict how the children conceptualized the plant. The annotations and captions indicated the children’s rationale to support the their illustrations and serve as an indication of how they used terminology related to plants. These models served as an accurate representation of their concept about how plants obtained food so that the teacher could attempt to facilitate changes in these ideas.

Contradictions between the children’s discourse and what they illustrated by drawing tasks indicated that there were inappropriate ideas related to the topic of photosynthesis. These illustrations provided the teacher with a visual model thought to represent the child’s unbiased conceptual referent (Curtis, 1988; Howe & Vasu, 1989; Ost, 1989). Dialogue between the teacher and a child was usually found to provoke the child to skillfully utilize rhetoric that seemed to complement the teacher’s discourse. However, dialogue between teacher and child that was referenced to each child’s illustrated conceptual extension was more laborious than soliciting rhetoric from each child that would satisfy the teacher’s conceptual intension. The
individual analysis of student’s drawing tasks required the teacher to circulate throughout the classroom and communicate with each student. Logistically, the teacher had to be able to view the child’s illustration and then quickly analyze the child’s conceptual model. When necessary, the teacher had to propose a reasonable challenge for the child to consider. According to Posner, et al. (1982), this is one of the requirements to induce conceptual change.

The question of whether or not the children would be able to produce reasonable illustrated graphic models and whether or not a teacher could reasonably analyze these in a classroom setting was considered during the pilot study. This was favorably resolved the first day. The pilot study indicated that a teacher could have easy and accurate access to the students’ ideas when viewing their illustrated models that resulted from the drawing tasks. It also suggested that most of these children had not compartmentalized scientifically correct illustrations related to photosynthesis like they had done with its verbal counterpart. This seemed to support London’s (1988) contention that what is transmitted verbally does not always represent knowledge. It was found that a teacher could target a conflict for each child that specifically engaged his/her conceptual model when there were differences between it and an orthodox model (Nussbaum & Novick, 1982). The use of starter pictures (Appendix A) and journals (Appendix B) provided the necessary focus and structure for the
children to begin their task. The illustrations and text produced by the children seemed to indicate that these children did indeed harbor many of the classic misconceptions about how plants obtain food.

During the pilot study, the teacher was able to manage the logistics involved in trying to use the children's illustrations as the basis for communication necessary to facilitate changes in their conception of how plants obtained food. Her primary task was to quickly scan the children's illustrated models, read the associated captions, and then determine if a discussion with the child was necessary. She considered the procedure reasonable and feasible for classroom use. It seemed that any teacher who had a clear determination of the model the child should be developing would be able to discern a path for the child to take in order to develop a more accurate model (Lederman & Zeidler, 1987).

Participants and Setting

The participants in this study were two 5th-grade classes from the Louisiana State University Laboratory School on the Baton Rouge campus. One class participated as the Experimental Treatment Group and the other participated as the Traditional Treatment Group. Each class had an enrollment of 26 students and was randomly assigned to participate in one or the other group. Two students from each class were dropped for reasons of experimental mortality or attrition. The classes at this school are
demographically diverse on the variables of race, ethnicity, and academic ability. The children in the elementary grades of this school are accustomed to hands-on, discovery modes of learning and are usually comfortable with social interaction in a classroom. Since the science program that these two classes were involved in had no formal text, they were comfortable with non-traditional learning materials. Both classes engaged in science classes four days per week with each class lasting about fifty minutes.

The two homeroom teachers for these classes have master's degrees and are experienced elementary school teachers. The teacher chosen for participation in the Experimental Treatment Group conducts workshops designed to orient teachers to the practices and philosophy of a hands-on, guided discovery program developed at the University of Hawaii called Developmental Approaches to Science, Health, and Technology or DASH. The basic pedagogical strategy for this discovery-type program involves a hands-on, inquiry oriented method of investigation by the students. The students are encouraged to reflect on their own answers to questions which are generated by the topic and by their progressive activities. The teacher directly intervenes only when the student is obviously straying from the goals of the topic. Otherwise, teacher facilitation toward a positive investigation is provided by dialogue between teacher and students. The Experimental Treatment Group teacher indicated that she has a strong personal and
professional commitment to the program. The teacher of the traditional treatment group indicated that the DASH program is appropriate for some topics, but is not appropriate to achieve all the goals she considers necessary for 5th grade students.

DASH activities are used extensively by the elementary grades teachers at the L.S.U. Laboratory School. Exceptions to this practice occur when certain topics not included in the DASH program are considered by the teachers to be of particular interest to the children or when certain main science concepts in the State of Louisiana Curriculum Guide are not addressed by DASH.

The two teachers participating in this project advised the researcher that activities that involve studying how plants obtain food are not included in DASH activities at the fifth grade level. However, they traditionally included activity on the topic of photosynthesis. The teacher of the class chosen to participate in the Traditional Treatment Group iterated her feelings about the necessity of students having a good foundation about the topic of photosynthesis since they would need such knowledge in later grades. Because of this, she felt that some traditional methods were needed to assure that the students were exposed to all of the material that they would need in later grades. The teacher representing the Experimental Treatment Group indicated that she normally addressed the same topics related to photosynthesis
as the Traditional Treatment Group teacher. However, her pedagogy and strategies reflect the philosophy she shares with the DASH program. The fact that their ideas about teaching photosynthesis so closely matched this project's pedagogical strategies intended for each treatment was entirely coincidental.

**Overview of Activities**

The intent of this project at the L.S.U. Laboratory School was to determine which of two modes of instruction would provide greater knowledge acquisition and retention and which would induce more effective conceptual change in those students who had a heterotrophic conceptual model of plants at the beginning of the study. The Traditional Treatment Group's mode of instruction was primarily didactic with some hands-on activities in the form of growing plants for the study. Didactic instruction usually does not consider a learner's prior knowledge related to a topic to be significant or assumes tabula rasa and provides data so that the learner will recognize a logical model and immediately accommodate to it (Lawson, 1988). The key to such a pedagogy is the expectation that the learner will remove-and-replace one idea with another as a result of dogma or logic. The intention is that students will logically and comprehensively recognize a rationale for specific orthodox concepts and accommodate to them (Harlan & Osborne, 1983).

Such a pedagogical strategy is appropriate for an objectivist oriented perspective of learning. This closely corresponds to a philosophy that
considers science to be a body of knowledge waiting to be delivered to a well managed class. Although there was plenty of seemingly contemporary student activity in the traditional classroom, there was no question that the agenda was accretion of knowledge.

The Experimental Treatment Group's mode of instruction also engaged students in growing plants. The difference was that the sequence of the activities with plants provided the students with most of their data. Their data were recorded by annotated drawing tasks visible to the teacher as illustrated models and written data entries in journals. The students were given a series of activities to engage in, recording the results of these activities in such a way that any contradictions between their illustrated models and the actual plants' responses to the manipulated environments would become apparent to the students and the teacher. The strategy and materials provided for the instruction were designed to produce this situation. Each of the two groups participated in thirteen days of research activities. Because of extracurricular activities and other school functions, the classes were not able to participate during all four days of each week. The total span of the classroom activities used for this project for each of the two groups was five weeks. The pretests, posttests, delayed posttests, and interviews added three more weeks to the total span of time for the classroom activities of this project. The total span from pretest to delayed posttest was 8 weeks for each group. However,
the activities for each of the two groups were not occurring simultaneously. The Experimental Treatment Group began their unit two weeks after the Traditional Treatment Group. Because the science period for each of the two groups was held at a different time during each day, the researcher was able to attend and monitor each class period of both groups.

Preliminary interviews were conducted with the teacher of each group before beginning the research project. Both were asked if they would try to achieve a specified goal during the course of the unit on plants. The goal was to have the children realize that plants are living organisms within the biosphere and they use the energy from the sun to produce food within their structures to continue the flow of energy and begin a food web. Both teachers considered that goal compatible with the unit on plants they usually provide for their students. The researcher met with the teacher of the Traditional Treatment Group for three, twenty-five minute sessions to review the content, activities, sequence, and method of presentation. We determined that there was a definite relationship between her unit and the goals of this project. She planned to use didactic methods to present the necessary data and hands-on activities for the students to accommodate to the data.

The Traditional Treatment Group teacher advised the researcher that she considered the information in her unit on plants and the goal agreed upon to be very important to her students. Because of this, she employed a very
structured unit that provided her students with all the information necessary for them to acquire the necessary concepts about the structure and function of plants. She felt a responsibility to provide her students with this information because they would need it in subsequent grades. This was a definite indication that her conception of the nature of science for children would influence her selection of classroom activities (Liederman & Zeidler, 1987).

The Experimental Treatment Group teacher and the researcher met for five periods of 30-45 minutes each. During these meetings, we examined the Tentative Daily Schedule (Appendix C) that outlined the procedure and sequence the students would be following during the course of the experimental treatment. The Experimental Treatment Group teacher advised me that she was encouraged by the preliminary details about the experimental procedure because it corresponded to the philosophy of the DASH program that she supported and used in her classroom. She was made aware of the rationale for the procedure, the materials that the students would be working with, and her role in the project. The procedure required that she circulate throughout the classroom daily and engage in dialogue with the students about the rationale for the illustrations and text that depicted their changing models of the plants. She was aware of how to conduct the brief interviews with the students without being judgmental about their comments, yet facilitate their individual progress toward an appropriate concept of how plants obtain food.
She had earlier developed a method of establishing rapport so that she could facilitate the students to become self-critical and utilize empirical means to determine answers. She studied some of the student-generated pictures and journals from the pilot study to become aware of the nature of the data students might be expected to produce and become sensitive to how she might respond to these students.

The classroom instruction for each group defined the experimental and traditional procedure being used. In both cases, the goal was to enable students to conceptualize plants as heterotrophic organisms that directly utilize the sun's energy and initiate a food source. The sun is usually perceived as an element with some ambiguous function that, nevertheless, keeps the plant healthy (Stavey, Eisen, & Yaakobi, 1987). These ideas held by children, and many adults, are considered to be particularly tenacious. This research project was designed to determine which of two teaching strategies, each representing a different epistemology, would effect more appropriate changes in how children believed plants obtain food.

**Experimental Treatment Group Instruction**

The intent of this treatment was to provide activities and instruction that would induce some conceptual change in those students who maintained a heterotrophic conceptual model of plants. It seemed reasonable that if a child’s predictions, based upon his/her current model, was incorrect, dialogue
and activities could facilitate them to reconsider their model. The assumption was that they should recognize that their model would no longer be able to generalize to plants in general. However, this can easily be ignored by the child unless attention is directed to it by the teacher (Hills, 1989; Watson & Konicek, 1990). A teacher’s role should be an active one that identifies inappropriate conceptions and explanations from the child, points out conflicts and discrepancies related to the child’s ideas, and then encourages the child to somehow deliberate these ideas (Smith, Blakslee, and Anderson, 1993). This might be the case, for instance, if a child’s model indicates that a plant receives its food energy source from soil. When children are faced with explaining how their model would account for a plant’s favorable response to a root medium without soil, they might reconsider their current model or they may try to develop an additional model even if it is contradictory to the first (Posner, et al., 1982). In such a case, the teacher should be able to spot conflicts of this nature by observing the child’s model and analyzing his/her discourse (Piaget, 1950; Posner & Gertzog, 1982).

The Experimental Treatment Group was exposed to a sequence of activities that were intended to expose a variety of misconceptions about how plants obtain food. These activities included drawing tasks that depicted students’ concepts of plants in ways that the teacher was able to identify and challenge these concepts. The children’s illustrated models were considered to
be their working models of the plants in the sense that changes in a student's ideas would be depicted on these models that illustrate their prediction of how the plant would respond when certain variables were manipulated. One way that children think about things and, as a result, grow and function cognitively is to recognize and resolve inconsistencies by noting the results of their predictions (Sigel, 1984; Lavoie & Good, 1986; Franklin, 1992). The researcher's contention was that the student's illustrated models would depict an accurate model of their ideas about how plants obtain food.

The Experimental Treatment Group students were provided with several researcher-prepared items that served as record keeping tools and assessment instruments. Daily records of students drawing tasks which represented their observations and predictions about the plants they used for study were kept on starter picture sheets (See Appendix A). These provided a basic starting point for the students to expand on (van Essen & Hamaker, 1990). The journals provided to the students were used to keep some of the teacher-provided resource information about plants and to complete statements given to them at the end of each class session. The variety of plants used for the daily activities were grown by the researcher and provided for the students. These were grown from commercially packaged bean seeds planted in a variety of media. Each plant was contained in a six-ounce styrofoam cup. On the first day of instruction, the students were given instruction about how to keep
visual records on their starter picture sheets, how to record data in their journal booklets, and some resource data to consider when conducting their daily activities with their plants. The following resource data were listed on the chalkboard for consideration: (1) Plants are living organisms and must grow as long as they are living. (2) Living and growing organisms require energy. (3) Living things, such as plants, use food for energy. (4) Water, minerals, and vitamins are needed by a plant to live, but are not food.

The overall scheme for instruction required the students to observe sets of real bean plants in a variety of environmental conditions and to record their ideas about how these plants obtained food. Their data were recorded by using drawing tasks to depict their conceptual models of plants and how these plants responded to the influence of various factors in the environment. Each illustrated model was drawn on dated starter picture sheets. The students observed plants under a variety of environmental conditions and provided an illustration to record their observations of how the plants were existing at the time of their illustration and state their predictions of how the plants would respond to the environmental changes after six days under the given conditions. The idea was to get them to commit to some idea of how the plant was getting the food energy it needed for life activities and to use their drawing as a statement much as they would write a statement. They also supplemented their drawings with captioned text. The teacher facilitated a
comprehensive construction of the model without directly advising the students how to construct a model of a plant obtaining food. "Semantic mapping and labeled drawings are complementary approaches to generating visual presentations of complex ideas that can be examined on the basis of complexity, interconnection of ideas, and appropriate hierarchies (Flick, 1993, p. 5). During each class period, the teacher circulated among the groups that consisted of four children each and discussed some of their rationale for their illustration of a plant’s response to the present conditions and their predicted changes based upon the indicated conditions. The dialogue between the teacher and students is examined later in the text.

Each day, the students and teacher interacted during the observation and prediction activities and engaged in more dialogue about how the students believed the plant got food. The purpose of the children's illustrated model was to have a readily accessible source of information for the teacher and the student so that the teacher did not have to rely entirely upon language to illustrate the children's concepts. It was easy for the teacher to view a child's whole meaning in one glance without wondering if the student really knew the meaning of statements such as, "sunlight, water, minerals, and nutrients making food for the plant" (See Illustration 4 on p. 33). The limitations of their knowledge about what the sun was doing relative to the plant became apparent in the illustration.
The teacher intended to make the students aware of how they thought the plants were responding to the environment in order to produce food energy. This was especially important for this early adolescent age when children begin to be capable of questioning their thinking and are able to be put in a situation where they can direct questions about the problems to themselves rather than by the teacher (Lawson, Lawson, & Lawson, 1984; Allison & Shirgley, 1986). Under such conditions, they would be made aware of any conflicts between their model’s illustrated response and how the plant actually responded over specified periods of time. When the teacher compared the children’s drawings before and after an activity, it was found to provide her with a rich source of information about how the children’s thinking had changed or, perhaps, needed to be directed.

The greatest opportunity for possible conflict with a student’s inappropriate concepts was provided by the sequence of plants in a variety of environmental conditions. Each set of plants represented an interaction between the plant and critical variables associated with plant nutrition and the photosynthetic process. The sequence of these operations and a child’s observations of a plants’ responses to changes in the variables of root media, light, and minerals provided the opportunity for conceptual challenge in the child who had made predictions about the plants’ responses that were based upon a model representing his/her conception about how plants actually
function. Drawing tasks depicting children’s predictions provided the teacher with some insight into how the children’s ideas about plant nutrition were evolving.

Bean plants and germinating bean seeds were provided to the students in regular potting soil and in a commercial non-nutritive artificial root medium called Perlite. For the activities during the first week, the plants in Perlite were irrigated with water and a commercial soil additive containing minerals and other nutrient supplements. This gave Perlite a function similar to soil. Each of the sets of plants was divided into those maintained in sunlight and those in darkness. This provided the children with sets of plants able to be manipulated according to the variables of light and root media. Since the students were already aware of how variables influence a situation and the significance of controlling variables, the teacher’s task was to make the students aware of what the experimental variables were so that the children did not inadvertently attribute any outcomes of the activities to some ambiguous source (Lucas & Tobin, 1987). The first week of classroom activity was designed to enable the students to see the effect of manipulating the variable of light on young plants and germinating seeds when root media and other environmental variables remained constant. The first set of plants and seeds were maintained in potting soil, one set exposed to light and the other kept in darkness. The same situation was provided for the set of young
plants in the Perlite with added minerals. This first week provided three separate experiments for the students. Each of the two root media and the set of seeds were tested in light and dark environments. The dependent variable was the perceived health of the plant when changes in growth and color were observed. The results of the first week's activities were supposed to suggest that plants without light cannot maintain health whether they are in soil or not. Also, it suggested that seeds do not need light to sprout. After germination, however, the young sprouts needed light to stay healthy. The students would later test the relative sugar concentration in the leaves of their test plants that were exposed to light and dark conditions. This would attempt to identify the role of light beyond the vaguely described task of somehow just keeping the plant healthy.

During the second week, the students compared their predictions to the actual outcome of their plants in both light and dark conditions. When a conflict between the student's prediction and the actual condition of the plant was observed, they were encouraged to consult with team members, reflect on journal entries, and examine their illustrations to analyze the situation and make changes to the illustrated model based upon how they perceived a resolution to the conflict. The teacher tried to facilitate more accurate models by using questions that might encourage the students to recognize significant relationships and reconsider some of their ideas about plants. Some of this
dialogue is examined later in the text. At the end of this week, the students did test the leaves of the plants in light and dark conditions with a glucose-sensitive indicator. Afterwards, they were provided with a model of how a plant makes glucose in its leaves for food energy. This resource model was viewed by most of the children with skepticism until they had exhausted most of their earlier rationale about certain plant activity. Interestingly, ideas from this resource model began to be incorporated into the students' discourse at least one week before it appeared in their illustrations.

During the third and fourth weeks, the students were looking for differences in plant performance which could be attributed to soil or a soil-like substance. To indicate that some nutrients, though not food, were gained from the soil, a comparison was made between bean plants in Perlite irrigated with water and dissolved minerals and those grown in Perlite irrigated with distilled water. After it was determined that minerals might be a significant component of root media, a comparison was made between the mineral enriched Perlite root media and the soil. This was supposed to illustrate that soil probably provides minerals that must be added to Perlite and plants without minerals have a deficit. This was supposed to discourage students' thinking of soil as a direct source of food. The intent of each of the comparisons was to create conflict with the students whose drawing tasks
indicated concepts that soil was the provider of food energy and that light provided some vague but necessary life support.

By the end of the fourth week, the students were consolidating each of their earlier pictures into one illustrated model representing how they believed a plant obtained food. The teacher's role was still that of observing illustrated models and challenging those that appeared to contradict a scientifically appropriate model representing a plant undergoing photosynthesis. After each child consolidated his/her models into one representative model, each small group of students consolidated their refined models into one model representative of the group. Ultimately, each group contributed their model for scrutiny by the other groups. This resulted in one community model representing how a plant obtains food (Appendix E). This task was performed on a starter picture transparency projected onto a screen. Representatives of each group used felt markers to make their contributions to the transparency.

**Traditional Treatment Group Instruction**

The Traditional Treatment Group was provided with the same basic data that the Experimental Treatment Group was given. Verbal notes and diagrammed structures were illustrated by an overhead projector. Very vivid explanations of and illustrations about the structure and function of the plant and its environment were provided. Each child was given ample time to copy notes and listen to the discussions. The Traditional Treatment Group used
student-made journals to maintain records of the observations of the plants that they grew for study. These were standard, spiral bound notebooks that the students used for each subject. The format and method of observation were dictated by the teacher. In addition to the journal, the students maintained an index card file that they recorded potential test questions on. These cards were used as flash cards for drill with peers to study for tests. For standard note taking efforts, the students used another spiral bound notebook to record the notes provided to them by teacher-prepared transparencies. The notes and accompanying illustrations were iterated by the teacher and the children were provided with appropriate questions which served as immediate feedback.

The material provided each day was introduced with a didactic lecture while students copied notes into notebooks from an outline displayed by the overhead projector. After the lecture, the children were called upon to affirm what was provided in the lecture and notes. The question/answer session was conducted with the apparent strategy to effect rote memorization of the provided data. For final resolutions, however, they were encouraged to refer to their notes related to the topic. Most of the interaction usually occurred between the teacher and those target students best able to provide accurate responses (Tobin & Gallagher, 1987). The others were expected to monitor these discussions in order to affirm that their notes were comprehensive and accurate. In such cases, there seemed to be a strategic selection of responding
parties until the answer was repeated in a fashion almost verbatim to what was provided. The teacher’s voice inflections indicated the relative importance of what was being discussed.

Using the above format to disseminate information, the curriculum involved the function of the major parts of the plant such as roots, stems, leaves, veins, and a very detailed description of how photosynthesis occurs in the leaves. This description included how chlorophyll absorbed the sun’s energy in order to enable the leaf to separate water into hydrogen and oxygen. The hydrogen combined with the carbon dioxide to form glucose (C₆H₁₂O₆) with residual oxygen given off as a waste product. The roots were carefully described as organs that absorbed the necessary water and minerals from the soil. The veins in the stems carried this material to the leaves. The chloroplasts were illustrated as the structures that absorbed the sun’s light energy to enable the leaf to produce the glucose sugar stored as starch. The plant used glucose for food.

To include a hands-on element to the class activity, the children were involved in several activities which seem designed to logically illustrate that plants did indeed undergo most of the processes described in the lectures. One such activity involved the use of celery stalks for students to observe colored water being drawn upward to the leaves by capillary action. Each child also planted several seeds in a clear plastic cup of moist soil so that they
could observe the growth of the plants when only moisture and light were provided. The containers were set in sealed plastic bags to preclude the administration of anything once the seeds were planted and irrigated with tap water. One of the plants was used to observe the root hairs so that the children could observe where this absorption process began.

As the plants began to emerge, the children were advised to keep a daily journal on the progress of the plant’s growth. They were directed to maintain records of changes in the size of the plant and to note that nothing was being added to the plant except daily exposure to sunlight. The records were kept by daily drawing tasks and by written records. This activity was conducted for ten minutes each day for a period of nine days. The teacher occasionally walked around to assure herself that the children were on task. They were reminded daily to observe, measure, and record the changes in the plants by drawing them and supplementing this by a written narrative of their observations. During this time they were advised that the only exogenous materials the plant received was water and minerals from the soil and sunlight and carbon dioxide from the surrounding air. The knowledge of how the plant absorbed the water and minerals and the observation of it’s growth, obviously supported by food, seemed a logical progression to induce the idea that a plant was self-supporting. To make certain that the plant produced a carbohydrate substance, the children conducted a test on their plants’ leaves.
Prior to the activity with the plant leaves, the students were allowed to see the effect of putting iodine on material that contained starch such as bread, potatoes, and crackers. Then, each child covered one of the leaves of a plant with black paper for a few days. When the paper was removed, the students tested the starch content of the covered and uncovered leaves to determine that when leaves are not exposed to sunlight, they do not contain starch. This seemed a logical indication that plants need sunlight to produce food. They were also given the opportunity to observe that when elodea plants are submerged in an aquarium, they displace the air in a test tube with an oxygen discharge from their leaves. Only plants exposed to sunlight and, consequently undergoing photosynthesis, were giving off oxygen.

Before and after each activity, the children engaged in a question/answer activity directed by the teacher. The material they reviewed was relevant to the activities they were engaged in. For example, during the starch-testing activities, a review of how a plant absorbed water and minerals through capillary activity initiated the lesson that described how a plant’s transport mechanism functioned. It was pointed out that this system provides some of the components necessary for photosynthetic activity to occur in the leaf. The chlorophyll and stomata provided a structural access for the sunlight and carbon dioxide.
Another activity that the students engaged in was question-writing. After each lecture, question/answer session, and plant observation, the students were directed to refer to their notes and, in pairs, write questions in a variety of styles that they felt might be asked on a test. Once this was done, the class conducted drills with the teacher to critique the quality of the questions. The answers to the questions were not discussed since they were already provided in the students' notes.

The researcher monitored the class activities of the Traditional Treatment Group daily and determined that the Experimental Treatment Group's strategies were not being adopted by the Traditional Treatment Group and that the instructional procedure was maintained according to prior arrangements with the instructor of the group. The nature of the instruction and the activities were conducted as planned.

Assessment Materials

The Traditional and Experimental Treatment Groups were both administered a pretest, posttest, and delayed posttest. The same instrument was used for all three tests and served both groups (See Appendix F). This instrument was originally developed by the researcher for use during the pilot study. The eleven short-answer questions were originally reviewed by the teacher of the pilot study group. This experienced teacher of gifted and talented students was also one of the developers for the State of Louisiana
Science Curriculum Guide for Elementary Grades. Several questions comparing plants to animals were discarded on the basis that they were superfluous to the study. A review by a science education professor with expertise in life sciences suggested several questions be re-phrased to decrease the likelihood of extraneous answers. Another review by a reading education professor and an elementary-grades teacher who is a trained presenter of special elementary methods affirmed the integrity of the revised test. The test was designed to elicit answers to questions about the sources of food energy for plants. These student-generated answers to the same questions over three separate instances were useful in analyzing changes in students' ideas about the topic. The instrument was evaluated on the basis of content accuracy, validity, and grade level appropriateness.

According to SPSS-X (SPSS, 1988), their procedure RELIABILITY computes Cronbach's Coefficient $\alpha$. When the data are not dichotomous, the measure "... is equivalent to reliability coefficient K-R 20" (SPSS, 1988, p. 873). "Formula [K-R] 20 is considered by many specialists in educational and psychological measurement to be the most satisfactory method of determining reliability. Cronbach's Coefficient Alpha ($\alpha$) is a general form of the K-R 20 formula that can be used when items are not scored dichotomously" (Borg & Gall, 1989, p. 261). When a reliability measure was used on the pretest of this study, a Cronbach's $\alpha$ of 0.77 resulted.
The journals, drawings, teacher and researcher field notes of daily classroom activities, and post-instructional interviews of both groups were used for the qualitative analysis of the students' ideas about photosynthesis.

Pretesting

The pretest instrument was administered to both groups by their teachers and monitored by the researcher. The students were advised that the test was part of a dissertation research effort by someone from the university and that the test itself would not affect their course grades. However, this unit on plants was part of their regular curriculum. The fact that the test was administered by their regular teachers seemed to convey to the students that the test was important. The results from this pretest were used as a covariate in calculating the inferential statistics for the project. The answers provided on this pretest were also used as one unit of comparison that was used to examine the changes in the quality of the students' answers over the course of the project.

Posttesting

Two posttests were administered to each participating group under the same terms as the pretests. In both posttest cases, the teacher of each group administered the test while the researcher monitored the activity. The first posttest was administered to each group on the day after the last day of instructional activity. The same instrument used for the pretest was utilized
for each of the posttests administered. The students were again advised to perform diligently even though the results would not affect their grade. The delayed posttest was administered to each group 16 days after the first posttest. The same procedures were followed for this administration that were conducted for the first two administrations.

The answers written by the students on these two posttests were also used to analyze the qualitative changes in student answers that occurred over the three tests. These changes were analyzed to look for changes in individual students' concepts related to how plants obtain food. The quantitative assessment on these tests were used for the completion of inferential statistics that provided a quantitative analysis of the differences in means between the two groups.

**Scoring**

The instrument used for the pretest and posttests consisted of eleven short-answer items. Scoring of the students' responses to these items was based upon the scorer's award of 0 to 3 points, in 1 point increments, for each response. The highest score was used for an answer considered to represent a scientifically appropriate response to the question. Two points were awarded to answers considered to be partially correct. One point was scored for a response which was considered scientifically inaccurate though not unrelated to the question. Zero score resulted when a student omitted the answer or the
answer was obviously not related to the question. Each test was scored first by the researcher. The researcher then enlisted the aid of a science education professor to serve as an outside evaluator. Once the outside evaluator completed scoring, the researcher conferred with her prior to completing his second scoring of the tests. The outside evaluator's rationale for scoring each item on the instrument was carefully discussed. After the outside evaluator completed the scoring, differences between the researcher and the outside evaluator were negotiated to a consensus. Once this was done, the researcher recorded the students' test scores according to the terms agreed upon by him and the outside evaluator.

Data Analysis

The experimental design for this study was a quasi-experimental, nonequivalent control-group design because the subjects were not randomly assigned to groups (Borg & Gall, 1989; Huck, Cormier & Bounds, 1974). The experimentally accessible groups represented the only two fifth-grade classes at the only participating school. Because of this, the comparative characteristics of the two classes were examined and evaluated in an attempt to determine if differences in their performance on the posttests would likely result from the treatment rather than from some extraneous variable. These characteristics are discussed in the opening of this chapter. Failure to make this determination could have influenced the internal validity of the treatment
results. The main threat to internal validity of a nonequivalent group design is that posttest differences could possibly be due to group differences (extraneous variables) rather than the treatment effect (Hinkle, Wiersma, & Jurs, 1988).

The quantitative assessment of this study examined the inferred differences between the students in the Experimental Treatment Group and the Traditional Treatment Group about their knowledge related to photosynthesis. The differences examined were the amount of knowledge gained and the retention of knowledge between the two groups during the time between the posttest and the extended posttest. The data from these two measures were analyzed using inferential statistics to determine if differences in the means of these scores were significant.

Since random assignment was not feasible for this study, the use of the pretest scores as a covariate provided some initial equivalence between the two groups. A SAS General Linear Model ANCOVA procedure with repeated measures was used to test for between subjects and within subjects effects to examine for differences in knowledge gain and differences in retention of knowledge about topics related to photosynthesis.

There were several sources of data that were able to be examined in order to analyze the qualitative changes in students' knowledge about how plants obtain food. Some of these data were children's artifacts such as test question responses, drawings, and journal entries. Some other data were the
field notes taken by the researcher and voice recorded dialogue between the teacher and the children during discussions about their illustrations. The evolution of the children's answers on their pretests, posttests, and delayed posttests were compared to the sequence of their illustrated models, the daily dialogue between teacher and children, and the interviews between selected students and the researcher.

After the posttests were administered, interviews were conducted with a selection of twelve children from each group. The teacher of each group made a selection evenly represented by gender and a three-tiered performance ability stratification. The purpose of the interviews was to elicit each student's model of how a plant obtains food. Analysis and other specifics about the interviews are discussed in the next chapter.
Results

This research focused on using drawing tasks by elementary grades students to illustrate their ideas about how plants obtain food energy to sustain life. The goal of each teacher of the two treatment groups was to guide students to recognize plants as autotrophic organisms that continue the flow of energy through an ecosystem by starting the food chain within themselves rather than obtaining food energy from an exogenous source. This goal corresponds to the recommendations of Project 2061’s Benchmarks for Science Literacy (AAAS, 1993) for students exiting fifth grade. Student-generated drawings in the experimental treatment were a primary unit of communication between the teacher and student. The illustrations that were produced as a result of the drawing tasks were assumed to represent the children’s concepts of how plants obtain food energy by interacting with their environment. This helped to provide a concrete assessment of the students’ prior knowledge related to plants and how this knowledge evolved during the course of instruction. It also provided a basis to validate the children’s discourse. Any departures from the orthodox concept of the autotrophic nature of plants were found to be more obvious when discussions with the children focused on their drawing tasks rather than trying to interpret the semantics of their classroom discourse. This strategy decreased the opportunity for the students to utilize terminology which, in syntax,
seemingly appropriate to classroom activities even though their semantic intension differed from orthodoxy. Semantic facades such as this can mislead teachers or other communicants into believing the child's discourse implies appropriate understanding. When children are successful at avoiding dialogue that would reveal inappropriate conceptions, it might preclude the need for cognitive processing by these children that could lead to more meaningful understanding (Lee & Anderson, 1993; Anderson & Smith, 1987). When students do reveal some degree of cognitive conflict in open dialogue, they usually perceive themselves to be in a vulnerable position. This has been acknowledged by admission of some students and by reasonable interpretation of the behavior of other students. Many choose to respond in ways that don't reveal their conceptual ecology. This is especially true when they feel that further dialogue will not satisfy any conflict or might necessitate the accretion of more data for them to be responsible for. Because of strategies such as this, children's knowledge about certain phenomena such as photosynthesis can remain limited to what they come to class with. This happens whenever what is experienced in class is not meaningful and quickly fades from memory. Any inappropriate concepts brought to class remain unchanged and continue to impede appropriate conceptual development because of inaccurate conceptual frameworks (Dreyfus, et al., 1990; Eaton, et al., 1983; Gunstone, et al., 1992).
Two research questions were posed to help focus the activity of this project. They were: (1) Do elementary-grades students receiving instruction about photosynthesis acquire and retain more knowledge when facilitated by teacher analysis of their drawing tasks than students who receive more didactic instruction? and (2) Can an elementary-grades teacher guided by students' drawing tasks that depict their concepts of photosynthesis effect more appropriate conceptual change than a teacher using didactic instruction? Data received from observation efforts by the researcher and from student artifacts such as tests, journals, and drawing tasks were used to analyze the results of this research project. Question 1 was examined by using inferential statistics to analyze the scores of the two posttests. Data analysis for Question 2 examined the quality of students' knowledge by using descriptive analysis of data to search for patterns and associations.

**Research Question 1**

The design for this part of the study was a quasi-experimental, nonequivalent control-group design because the subjects were not randomly assigned to groups (Borg & Gall, 1989, Huck, Cormier, & Bounds, 1974). The experimentally accessible groups represented the only two fifth-grade classes at the only participating school. The quantitative assessment of this study used students' test scores to examine the differences in their knowledge about how plants obtain food. Differences between the Experimental
Treatment Group and the Traditional Treatment Group were measured and analyzed at the posttest and the delayed posttest. Since random assignment was not feasible for this study, the use of the pretest as a covariate provided some initial equivalence between the groups. The posttest and delayed posttest scores were used as the dependent variable. The data from these measures were analyzed using inferential statistics to determine if differences in the means of these scores was significant.

A SAS (1982) General Linear Model 2 X 2 ANCOVA procedure with repeated measures was used to test for between and within subjects effects.

Table 1 indicates the means and standard deviation for each of the two treatment groups on the pretest, posttest, and the delayed posttest.

Table 1. Means and Standard Deviations for the Experimental Treatment Group (ETG) and the Traditional Treatment Group (TTG) on the Pretest, Posttest, and Delayed Posttest.

<table>
<thead>
<tr>
<th></th>
<th>Pretest</th>
<th>Posttest</th>
<th>Delayed Posttest</th>
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</thead>
<tbody>
<tr>
<td>(ETG)</td>
<td>Means</td>
<td>13.33</td>
<td>27.98*</td>
</tr>
<tr>
<td></td>
<td>Std. Dev.</td>
<td>1.52</td>
<td>4.87</td>
</tr>
<tr>
<td>(TTG)</td>
<td>Means</td>
<td>14.25</td>
<td>23.22*</td>
</tr>
<tr>
<td></td>
<td>Std. Dev.</td>
<td>2.13</td>
<td>3.82</td>
</tr>
</tbody>
</table>

* adjusted means

Table 2 indicates the results of the SAS General Linear Models analysis of covariance. Time by pretest (Table 2) indicated no significant interaction between the slope of the covariate and the dependent variable and that a
common slope could be assumed. The statistical control necessary for equating the differences in the pretest of the two groups or an assumption of linearity between the two posttests and the covariate was indicated by Pre (covariate). A significant linear component was indicated.

Table 2. Summary of Repeated Measures Analysis of Covariance of Two Teaching Methods On Learning Groups Over Time Between The Posttest and Delayed Posttest.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Type III SS</th>
<th>Mean Square</th>
<th>F Value</th>
<th>Pr&gt;F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main effect of Group</td>
<td>1</td>
<td>471.41100</td>
<td>471.41100</td>
<td>17.55</td>
<td>0.0001</td>
</tr>
<tr>
<td>Pre (Covariate)</td>
<td>1</td>
<td>253.41500</td>
<td>253.41500</td>
<td>9.44</td>
<td>0.0036</td>
</tr>
<tr>
<td>Error A</td>
<td>45</td>
<td>1208.41800</td>
<td>26.85400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main effect of time</td>
<td>1</td>
<td>0.00338</td>
<td>0.00338</td>
<td>0.00</td>
<td>0.9858</td>
</tr>
<tr>
<td>Time x Group</td>
<td>1</td>
<td>0.81727</td>
<td>0.81727</td>
<td>0.08</td>
<td>0.7818</td>
</tr>
<tr>
<td>Time x Pre</td>
<td>1</td>
<td>1.60374</td>
<td>1.60374</td>
<td>0.15</td>
<td>0.6981</td>
</tr>
<tr>
<td>Error B (Time)</td>
<td>45</td>
<td>473.64625</td>
<td>10.52547</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comparison of Means

Figure 1.
The interaction of time by group was not significant, indicating that the differences in the means between the two groups did not change differently over time between the posttest and the delayed posttest. Figure 2 indicates essentially parallel lines illustrating changes between the two groups. The other within subject effects, main effect of time (Table 2) indicates that the differences in means averaged over groups at the posttest was not significantly different from the differences at the delayed posttest. This suggests that there was no significant difference in retention of acquired knowledge of the two groups over a fifteen day time period between the two posttests. The test for between subjects effects or main effect of groups indicates that there was indeed a significant difference in the means between the two groups averaged over the posttest and the delayed posttest. Further, simple main effect analysis of group within each time indicates a significant effect of group at the posttest and at the delayed posttest (Table 3). As a result of this, the means in Table 1 indicate that the Experimental Treatment Group's knowledge acquisition was significantly greater than that of the Traditional Treatment Group at the posttest and the delayed posttest.
Table 3. Summary of Simple Main Effect of Group at the Posttest and Delayed Posttest.

<table>
<thead>
<tr>
<th>Time</th>
<th>Source</th>
<th>DF</th>
<th>Type III SS</th>
<th>Mean Square</th>
<th>F Value</th>
<th>Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posttest</td>
<td>Group</td>
<td>1</td>
<td>255.7424</td>
<td>255.7424</td>
<td>15.69</td>
<td>0.0003</td>
</tr>
<tr>
<td></td>
<td>Pre</td>
<td>1</td>
<td>147.6691</td>
<td>147.7424</td>
<td>9.06</td>
<td>0.0043</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>45</td>
<td>733.6225</td>
<td>16.3027</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delayed</td>
<td>Group</td>
<td>1</td>
<td>216.4858</td>
<td>216.4858</td>
<td>10.27</td>
<td>0.0025</td>
</tr>
<tr>
<td>Posttest</td>
<td>Pre</td>
<td>1</td>
<td>107.3497</td>
<td>107.3497</td>
<td>5.09</td>
<td>0.0289</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>45</td>
<td>948.4419</td>
<td>21.0764</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Overall, the analysis of the quantitative scores of the posttests seems to suggest that students who participate in the experimental treatment score higher than those in the traditional treatment. However, although students in the experimental treatment yielded higher mean scores, the statistical indications are that knowledge retention was not significantly different between the two groups over a 15-day period.

In spite of this, we cannot assume that knowledge acquisition and retention by these students represents their conceptual framework related to plants (Krenz & Sax, 1986). Because of that, this project examines some of the qualitative aspects of the students' knowledge with the realization that both research methods have limitations (Bowman, LeCompte, & Goetz, 1986).

**Research Question 2**

Can an elementary-grades teacher who uses students' drawing tasks to depict their concept of photosynthesis effect a more positive conceptual change
than a teacher using didactic instruction? To answer this question, one certainly has to look at the quality of the change in knowledge of the subjects. It is possible that students can score reasonably well on written tests even though they harbor misconceptions about how plants obtain food energy. This can occur when their responses are well supported by accurate, compartmentalized knowledge acquired by accretion of data. Students can maintain their old concepts and still relate new data to these concepts even though the new data cannot be assimilated into an appropriate framework. From a constructivist point of view, one can understand that concepts are formed and also changed when new knowledge is perceived to be related to concepts that structure the frameworks linked to the new knowledge (Shuell, 1987). As a result, the accuracy and the broadness of these concepts depends upon links being associated between these concepts and other concepts within frameworks (Novak, 1967). The implication is that when new knowledge is perceived to be related to inappropriate concepts within a conceptual framework, misconceptions might result. In the elementary-grade classrooms, children bring with them many of their own established ideas about scientific and natural phenomena. If improperly handled, many of these prior ideas might interfere with the science topics that are being taught in a classroom because the teacher might incorrectly assume a child's prior knowledge about a topic will support the lesson. Roth and Anderson (1987) recognized some of
the problems resulting from prior knowledge of when they failed to identify and address the children’s misconceptions about photosynthesis prior to teaching a unit.

Sources of data considered for analysis from the two treatment groups were their written answers to questions on the three tests, student journal entries, researcher field notes of class activities, and interviews with selected children. Additional sources of data from the Experimental Treatment Group included transcripts from voice recordings of daily interactions between the teacher and students during the teacher’s classroom analysis of the children’s drawing tasks and from their pictures depicting their conceptual models of plants. The criteria for the selection of students to be interviewed included differences in gender and scholastic achievement. Six males and six females were chosen, two from each of the groups of high, middle, and low achievers from each of the two treatment groups. The teacher of each group provided a stratified list for the project.

The quality of the students’ knowledge about plants was partly determined from an examination of the students’ answers to test questions. This helped to determine how the students’ perceived a food source for plants and their knowledge of how food functions for an organism. Roth and Anderson (1987), Smith, Blakslee, and Anderson (1993), Lee and Anderson (1993) had determined that one problem with teaching photosynthesis to
children was that they had no idea what the function of food really was. They concluded that a concept of food as the source of energy for an organism was one requisite for understanding photosynthesis. It must be perceived as a source of energy rather than just something that is eaten. In addition to this, energy must be perceived as that which makes the body do what it needs to grow and, as a result, stay healthy. The above researchers suggested these ideas about food energy as a prerequisite to perceiving photosynthesis as a special way that plants get their food. These special characteristics must be part of the conceptual framework that includes plants. Examining the evolution of students' answers to the same questions over the course of the pretest, posttest, and delayed posttest helped to determine if the students' concepts were evolving into those considered appropriate to understand photosynthesis as a source of food for plants and to infer whether or not there was positive conceptual change over the course of the instruction (Goetz & LeCompte, 1984).

**Traditional Treatment Group**

Table 4 illustrates the changes over time of the Traditional Treatment Group's understanding of what food was from pretest to delayed posttest. It indicates the percentage of Traditional Treatment Group students who stated that the function of food was to provide energy for an organism. According to *Benchmarks for Science Literacy* (AAAS, 1993), between fifth and eighth
grades, students should be aware that organisms need a source of energy such as food to stay alive.

**Table 4.** Percentage of Traditional Treatment Group Students Who Indicated That Food Provides Energy for an Organism.

<table>
<thead>
<tr>
<th>Test</th>
<th>Pretest</th>
<th>Posttest</th>
<th>Delayed Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>29</td>
<td>13</td>
<td>00</td>
</tr>
</tbody>
</table>

Although almost one third of the Traditional Treatment Group students who stated on the pretest that food provides energy for a plant, none stated this on the delayed posttest. Analysis of the answers to questions on the delayed posttest that relate to food as a source of energy indicated that almost all of the students in the Traditional Treatment Group felt that food only had some vague function of keeping the plant healthy. Apparently, these students did not perceive a connection between the sun as a source of energy and food as a source of energy for an organism. As stated earlier, researchers found that when children did not conceptualize food as a source of chemical energy, it hindered their understanding of plants being able to synthesize food; a major difference between plants and animals (AAAS, 1993).

Table 5 indicates the percentage of students from the Traditional Treatment Group who expressed their understanding that plants obtain food energy intact from the soil or dirt. There was no indication that the plant was able to synthesize food. This was determined from answers to questions on
the three tests taken. It has been recommended that students understand that plants use energy from light to produce food and that this is a key distinction from animals which consume energy-rich foods (AAAS, 1993).

Table 5. Percentage of Traditional Treatment Group Students Who Indicated That a Plant's Food is Obtained Intact From the Soil or Dirt. There was no indication that the plant synthesized food.

<table>
<thead>
<tr>
<th>Test</th>
<th>Pretest</th>
<th>Posttest</th>
<th>Delayed Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>21</td>
<td>08</td>
<td>21</td>
</tr>
</tbody>
</table>

On the posttest, immediately after instruction, only 8% of the Traditional Treatment Group students stated that a plant's only source of food was soil or dirt (Table 5). This indicated a considerable improvement over the 21% who thought otherwise prior to instruction. However, by the delayed posttest, it seems that the apparent improvement indicated on the posttest was lost since 21% again stated that plants received their food intact from soil or dirt without any indication that a plant synthesized food.

In Table 6, column A indicates the percentage of students from the Traditional Treatment Group who stated that plants were at least autotrophic. Some students in this group, however, still believed that the same plant could also get food intact from the soil or dirt. This is indicated in column B. The difference between columns A and B, or column C, represents the percentage
of students who indicated that the photosynthetic process was the only source of food for plants.

Soon after the instructional activity was completed, the posttest indicated that 75% of the students stated that plants synthesized food. Only 13% of the posttest group stated that plants could also get food intact from soil or dirt. However, on the delayed posttest, only 33% of these students indicated that plants are autotrophic. This means that although 75% of students on the posttest, or immediately after instruction, stated that a plant's only source of food was through synthesis within the plant, only 33% still believed this at the time of the delayed posttest almost two weeks after instruction.

The most positive effects of the Traditional Treatment Group's instruction were indicated on the posttest that was administered soon after instruction. One inference is that much of what was indicated on the posttest

<table>
<thead>
<tr>
<th>Test (% Traditional Group)</th>
<th>(A)</th>
<th>(B)</th>
<th>(C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>66</td>
<td>38</td>
<td>28</td>
</tr>
<tr>
<td>Posttest</td>
<td>88</td>
<td>13</td>
<td>75</td>
</tr>
<tr>
<td>Delayed Posttest</td>
<td>71</td>
<td>38</td>
<td>33</td>
</tr>
</tbody>
</table>

Table 6. Percentage of Traditional Treatment Group Students Who Indicated (A) That the Plant is Able to Synthesize Food and (B) Percentages of the Same Group Represented by A Who Indicated That the Plant is Also Able to Get Food Intact From the Soil. (C) Indicates Percentage of Students Who Stated That a Plant's Only Source of Food is What it Synthesizes.
might have been the result of compartmentalized data which began to lose its impact as time between the posttest and the delayed posttest increased.

Although many students scored well on the posttests because they were able to recall some details about photosynthesis, their heterotrophic models of plants were evident. Overall, the inference is that some of the children seemed to compartmentalize the data about plants being autotrophic while still maintaining that plants were heterotrophic and also able to get food intact from a source outside of itself. The basic concept of a plant was inappropriate for most of these students even though they were able to improve posttest scores. Analysis of the posttest scores suggests that many students of the Traditional Treatment Group were not sure what it meant for a plant to undergo photosynthesis. An examination of twelve students’ interview statements also seemed to indicate this. Most of these students indicated that even though they could state some facts about photosynthesis, their old model of plants obtaining food analogous to animal methods of eating still existed. Excerpts from several Traditional Treatment Group students were selected to illustrate this.

I: What is photosynthesis?
S16: Like, uh, photosynthesis is the food making process, and, ... the thing that the water, ...that the sunlight, the carbon dioxide, and all that stuff, is in the chlorophyll, and the chloroplasts is needed to make that food.
I: What does it do with water, sunlight, and carbon dioxide?
S16: Uhh, let's see. It makes oxygen, ummm, and the hydrogen and the oxygen, uhh is used as waste and the hydrogen mixes with the carbon dioxide and makes the sugar and the starches and ummm ....
In spite of this definition of a food making process, the child’s old model surfaced when a discussion about food for the plant persisted.

I: What is food for the plant?
S16: Food for the plant is ... All I can say is that anything that the earth would give it to live is all it needs to live. (delay) Or, if you like ..., if you have your own plant, whatever you give it, or what it needs, whatever you give it is what it needs to eat.

Another student was asked about the source of food for plants. Her responses covered a little of everything just to make sure that plants, as she knew them, would not go hungry.

I: What is plant food?
S23: Oxygen, hydrogen, uhh, chlorophyll, ummm ... (long pause)
I: Do you think that it might get food from the soil?
S23: A little bit.
I: When might it get food from the soil?
S23: When it gets the water.
I: Is water food?
S23: Yep.
I: So, when does it [plant] need sunlight?
S23: When it is about to feed itself.
I: When doesn’t it need sunlight?
S23: When you put plant food in it.
I: If we gave the plant Miracle Gro, would the plant still have to make its own food?
S23: No.
I: Then, where does a plant get its food from?
S23: Sunlight.

Some of these students’ responses seemed to be a mixture of classroom knowledge and a child’s real-world concept of how a plant obtains food. The following is another example of the same thing.

I: How do they [plants] go about getting their food?
S04: Ummm, I think that that’s weird. Unnn, they take in sunlight (unintelligible). I didn’t think that plants used it.
I: How do they use it?
S04: They use it to separate the water when it goes through photosynthesis.
I: What does that do for it?
S04: It divides the hydrogen and the oxygen. (pause) That’s pretty much what it does. Uhhh, they gather the, ummm, water, and minerals, they get sunlight and CO₂, and put that together and they get the food.
I: Where does that happen?
S04: In the green leaf.
I: What's the other source of food for the plant? (Other sources were never discussed in class or between the interviewer and students.)
S04: Ummm, it gets it from the dirt.
I: How does it get into the plant?
S04: Uhhh, through the roots.
I: What is the process whereby it makes food?
S04: Photosynthesis.

This seemed to indicate that the student's old model was still intact, though an addendum to this model was included.

The next student provided an indication of rhetoric that was beginning to cause conflict when she became conscious of it. Her rationale, however, was still her model of a plant that was analogous, in some ways, to humans.

I: Where do they [plants] get most of their food from?
S14: The sun, and like air and CO₂. (pause)
I: How does that become food for the plant?
S14: Uhhh, (pause) ummm, I guess there is some kind of nutrient in the CO₂ and in the rays of the sun. And, uhhh, they sort of mix it with water and it's sort of like a drink. Like Kool-Aid. We have to mix the powder and the water to make it liquid and taste. I guess that's what they have to do.

She is suggesting that something outside of the plant is already food and becomes useful to the plant when mixed with water. There is a blending rather than actual synthesis of food within the plant. The old models are strong and provide the rationale for most of the conscious thinking and mental model-making, such as analogies, for explanations. Concepts are considered to be, among other things, an idea or understanding of what something is (Kolesnik, 1970). This child's understanding of what a plant was seemed to be a combination of what she knew people to be and whatever superficial characteristics of plants were obvious enough to classify them different from
people. This seemed to influence why she thought plants should use what they have available for food. Her ideas of plants are not unique.

The remainder of the conversation with this same child began to illustrate one of the common problems that most of these students from the Traditional Treatment Group had when they made an attempt to generalize their classroom rhetoric to their conceptual models of plants.

I: Can the water mix with anything in the soil to help the plant?
S14: Ummm, Uhhh, yeah, ahhh, ummm, sure! There's gotta be some nutrient in the soil because, if, ummm, if there wasn't anything in the soil, why should they use soil to, uhhh, keep the plants ..., why not just put them in a pot without anything to hold them up?
I: How would the plant get that stuff?
S14: Uhhh, the root hairs and the root, uhhh, ... it would absorb the water and the food, and they, uhhh, the roots would bring it up to the stem, the stem would bring it up to the leaves where they make their food.
I: (long pause) I must have misunderstood you. Is the root getting the food or is the leaf making the food?
S14: The leaf is making the plant food, I think. And ..., but, I think that, ..., the, ... the leaf, ... the root ... is just bringing the food to the leaf.
I: Is the leaf changing the food or what?
S14: Uhhh, I think ... I think that the, uhhh, ... the leaf makes it and then sends it out to the rest of the plant.
I: Then, what about the plant food that you fed the plant?
S14: Ummm, ... I think the leaves would absorb the plant food.

It seemed to be a difficult task for these children to have to draw from their conceptual model and a rhetorical model of a plant to get through the increasingly complex maze of the real world and the classroom world. Normally, however, children are quick and develop the necessary semantic skills to merge these two models and skillfully navigate through a teacher's web of questions without any changes in what they really think.

The final statement by S14 was a very good example of the old plant model well protected by skillful use of rhetoric.
I: Are you comfortable with how plants get food?
S14: Umm, Ummm, yeah.
I: Photosynthesis, ... are you familiar with that?
S14: Yeah! That's the food making process of the plant.

The next student was aware that certain rote answers were being solicited by a teacher. There was no attempt to act like it made sense to him. His real responsibility was to recall the procedure as it was given to him.

S07: It, uhh, ... chlorophyll attracts the sunlight, ... the sunlight is basically the food [?] and it, it goes through ... (long pause)
I: What kind of food is made?
S07: It makes sugar, ummm, all I can remember is sugar. (pause)
I: How does it get this sugar?
S07: It uhh, (pause) when the chlorophyll traps the sunlight, it separates the water into hydrogen and oxygen, and then, ... water comes in somewhere, .... (pause).
I: How does the food get into the plant?
S07: It goes in through the leaves and chlorophyll will trap it in the leaves. (pause)
I: How does the food get into the leaf?

This is where some children invoke the "magic moment" or try to say the right words they heard in class. The conflict between what was compartmentalized and what they know to be their model of a plant eventually begins to surface.

S07: The sunlight just shines on the leaf, and the chlorophyll traps it and, uhhh ... well, uhhh, the veins, the veins will carry the food, like up to the leaf.
I: From where?
S07: Like from the root hairs, to the stem and then to all the leaves.

This child's model was still one of an earth-eating plant. When children get into a jam, they usually revert back to the things that they know to be true. They can explain them that way. Each of the other children interviewed suffered from conflict between what they had been told in class and what seemed to work for them with their conceptual model of a plant. Nothing had been done in their classroom to challenge their prior ideas when
there was a conflict with classroom data. They were encouraged to simply memorize a procedural aspect of how a plant undergoes photosynthesis. However, these students were not able to transform the classroom activities they were engaged in into data able to be integrated meaningfully into their preexisting structures. They seemed to accumulate the data that were presented to them in a logical, linear way and were expected to accommodate to the data from these presentations. According to Smith, et al. (1993), the most common model that most children have of plants obtaining food is similar in manner to that of animals. These misconceptions seem to persist because of the usefulness the learner's of prior knowledge and the ineffectiveness of some pedagogy to change these misconceptions. A child's related concepts within the framework that includes plants are linked in a cognitive matrix that is not easily restructured by linear logic alone.

Learners need to be placed in situations that perturb them enough to feel a need to seek resolution to cognitive conflict (Lorsbach & Tobin, 1992). These kinds of situations are referred to by Lubeck and Biddel (1986) as a process of creation. "Creativity is the process of sensing gaps or missing elements and forming hypotheses concerning them" (p. 33). They compared this to Piaget's equilibration model. This kind of activity requires lateral or divergent thinking and time to restructure. However, it is not likely to occur in a classroom unless facilitated by a teacher.
When the answers to specific questions on the posttests were examined, contradictions were apparent. Most children gave clear indications that they were referencing more than one model of a plant. The contradictions resulted when they attempted to semantically integrate classroom data about autotrophic plants into their heterotrophic model of a plant. There was little indication of change in their concepts about how plants obtain food. Most of these Traditional Treatment Group children still adhered to the belief that plants obtained food from a source exogenous to the plant structure. There were no overwhelming indications that food was considered to be a source of energy or that the sun was responsible for helping a plant synthesize food.

An examination of some of the characteristics of the pedagogy utilized during the Traditional Treatment Group's unit on plants might provide some indication about what happened. During the thirteen days that the students were studying plants, eleven of these class periods involved lectures to provide notes to the children, a review of the previous days notes, and drill and practice to provide rote answers to questions related to a plant's process of obtaining food. The question/answer sessions solicited answers verbatim to the notes the children were recording. One of the things that seemed to discourage any dialectic activity in the classroom might be that no concrete references were used during discussion. Although real plants were sometimes present, the children were, on many occasions, asked to recall how something
appeared to be on a transparency from a few days before rather than from a reference to real plants.

Throughout the unit, not many children were active participants. Active is used in the sense that it enables the learner to manipulate the learning environment for the purpose of testing his/her cognitive model when data are contrary to it or disequilibrium exists (Flick, 1993). Dellarosa, et al., (1988) found that didactic classrooms provide words and phrases that students are unable to readily map onto their cognitive structures. As a result, the learner ignores prior knowledge and superficially looks for key words and the favored context in which to use these words. These Traditional Treatment Group students seemed to know that all of the data necessary for the examination would be provided to them by the teacher and, because of this, other activities were not as important as recalling data in a manner that satisfied the teacher.

There was one particularly interesting aspect about the way the topic of photosynthesis was presented to this class. The students were engaged in an activity which required them to cover one leaf of their plants with black paper. After a few days, the covered and uncovered leaves were tested for starch. The students were advised that carbon dioxide, water, light, and chlorophyll were used by the plant to produce food. It was emphasized that light provided the necessary energy for the chemical synthesis to occur.
Sunlight was trapped by the chlorophyll in the leaf and its energy was used to split water into hydrogen and oxygen. They were told that this hydrogen combined with the carbon dioxide to produce sugar and starch. The leaf was described to the children as "... the little kitchen of the plant". The interesting thing was the detail provided to them about the splitting of the molecules necessary for photosynthesis to occur. Roth and Anderson (1987) noted that too much detail seems to confuse younger students making it more difficult for them to initially assimilate new data into existing concepts. On the last day before the end of the unit, one child's sickly looking plant was discussed. When the teacher asked why anyone thought that the child's plant was not prospering as well as some of the other plants, student responses included temperature, pot size, water amount, and stuff in the soil as likely variables that could affect plants. Only one child mentioned anything about the effect of sunlight. Most of the variables the children considered significant were those they were probably aware of prior to the instruction. Lee and Anderson (1993) indicate that in order for students to become motivated to learn science, they must engage in tasks that enable them to integrate their personal knowledge with the proposed scientific knowledge. Such activities require students to describe things, predict outcomes, explain what happens, and take control of the processes of learning. Good science activities encourage the students to interact with the learning environment.
This interaction includes being able to change or modify this environment until a consensus has been negotiated among the learner’s conceptual framework, the teacher, and the learning environment (Flick, 1993).

Experimental Treatment Group

The use of drawing tasks as a basis for direct communication with the students was selected because children can construct illustrated models which depict their reality even when they lack or misunderstand terminology appropriate for verbal descriptions. As Silver (1981) stated, "Children's drawings are pictorial devices that can represent reality . . ., and thus reflect their thinking (p. 4). It was deemed important for the teacher to see the child’s model of how a plant obtained food without worry that a semantic facade consisting of appropriate terminology would be used to replace the child’s real understanding about plants.

The daily regimen that the students participated in is detailed in the Tentative Daily Schedule (Appendix C). Field notes of classroom activities were kept by the researcher and were used with other data to identify some of the factors which might have influenced changes in some students’ concepts. The sequential changes in the students’ conceptual models were examined by analyzing the changes in their captioned drawings that depicted how plants responded to different environmental conditions and their responses to questions and challenges provided by their teacher. These conversations were
recorded by a small voice recorder during the daily interaction between student and teacher. Interviews that were conducted with twelve selected students provided a summary of each of the students’ work with their plants. Analysis of transcripts of these interviews contributed to the data that were used to illustrate a pattern of conceptual change. The three tests administered also served as a periodic record of how the students’ responses to specific questions changed during the course of instruction and activities.

Sequential data analysis of three selected students was used to illustrate how their ideas about how plants get their food changed during the course of the activities. One student was randomly selected from each of the three achievement level groups that the students were assigned to by their homeroom teacher. These were chosen from the twelve students who were interviewed. These three students were two females, S2 and S6, and one male, S9. An examination of the answers provided by these three students on the pretest indicated that all three considered something to be food if it was able to be consumed by the organism and that sunlight had some ambiguous factor that was essential for the growth of plants. This was a common conception among almost all of the participants in this study. All three of these students stated on the pretest that food for plants was water. In addition, S2 stated that food also comes from the minerals in water. S9 indicated that food was absorbed by the roots and that rain was the primary source of food.
S6 also indicated that people provided fertilizer for food and added sun as an occasional source of food. According to S2 and S9, the roots were like mouths. However, S2 used an analogy similar to an animal digestive system which stated that good and bad things were separated out in the plant. Both S2 and S6 indicated that the soil was a primary source of food and that the roots and stems brought food up to the rest of the plant. S9 stated that leaves soak in food. All three believed that sunlight was used by the plant for growth. S2 also indicated that the sun functioned to dry up excess water in order to concentrate food. Their conceptions of plants were typical of the other students in the Experimental Treatment Group.

On the first day, the students were provided with the necessary materials to draw and otherwise record their ideas about plants. They were initially provided with the following resource data to consider when carrying out their daily activities with the plants: 1) Plants are living organisms and must grow as long as they are living. 2) Living and growing organisms require energy. 3) Living things, such as plants, use food for energy. 4) Water, minerals, and vitamins are needed to live, but are not food. They were asked to refer to this periodically as they worked with their plants and recorded their data. While they were working, the teacher circulated among the students to guide them in the use of drawing tasks to keep visual records of their activity. She also asked the children to provide rationale and captions
for their illustrations when necessary for clarity or emphasis. The intent was to make them perceive their drawings as a statement much as it would be a written statement. The teacher was encouraged by the researcher to discuss with the children what their pictures represented and how they corresponded to real plants. Their drawing tasks provided a medium for communication that discouraged connotations as primary statements that might disguise the children's real meanings. When the teacher was able to challenge some of the illustrations produced by drawing tasks or when their predictions were contradicted by the actual occurrence of the plant, the children had to correspondingly change the original visual statement instead of just finding a convenient verbal alternative to satisfy the situation.

The teacher's main task during the early stages of the activities was to get the students to recognize the significance of variables such as light, water, minerals, and rooting media on the status of the plants. The teacher advised the researcher that the children showed competence in recognition, control and manipulation of variables during the weather unit that preceded this project. These skills were apparent during their daily activities. Beginning activities focused mostly on observing and predicting what would happen to the plants and seeds that were rooted in different media such as soil and Perlite under lighted and dark conditions. The soil used was standard potting soil that was irrigated with tap water. Soil was portrayed as a medium to supply minerals
and moisture to the plant and could be replaced by Perlite as long as minerals were added. Perlite was described to the children as a non-nutritive material that had to be supplemented with a mineral solution to simulate soil. Variables such as location, moisture level, type of plant, and time were kept constant. The students were aware that the only variables manipulated were light and root media. The primary intent was to illustrate that light and minerals were significant variables. In order to focus upon the fact that plants needed light for reasons other than for the very vague, intuitive reasons of healthy growth, a glucose-sensitive material was provided for the children to test the sugar concentration in the leaves of plants that were in light and dark conditions. Since glucose was identified as food for the plant, the target inference was that light is directly associated with food. This strategy was apparently effective during the course of the project. The children gradually began to shift from soil as the most significant food factor for plants to that of light and components in the soil. After the glucose tests were completed on the fifth day, the children were provided with the following additional resource data: 1) Plants use sugar for food energy. 2) Water, minerals, and vitamins are not food. 3) Food is chemical energy. These were suggested for consideration as they continued working with their plants.
Analysis of Data From Week One

Examination of some of the dialogue, journal entries, and students' illustrations that depicted how they perceived plants began to indicate some of their changing ideas. S6 indicated on the pretest that plants need light for nourishment and got food from soil, light, water, and fertilizer. Major items such as soil, light, and water were clearly indicated on her first drawing (Illustration 6) and certainly influenced her predictions of plant's responses to light and dark environments. Her reason for plants not doing well in darkness was also indicated in her daily journal. "Water and light work together. The plant will get too soggy." These were her reasons for the failure of her plant in darkness. On the third day (Illustration 7), there was a small indication that Perlite, water, and sunlight were "part of the food". That seemed to agree with her journal entry indicating that "plants don't need soil to grow because Perlite has everything that soil does".

At that point, she believed the Perlite plants in dark would survive but not thrive. It seemed that she had no clear source of food. There were so many independent sources of food indicated that her plants could seemingly survive under any circumstances. One thing was certain, however. She still perceived food coming from a source outside of the plant. The substance was food before it entered the plant. She seemed to be an opportunist about where the food was coming from. Any reasonable source was considered to be
primary. Consider the conversation between her and the teacher on the third
day of activity.

I: [her name], tell me what you think is going to happen to your plant in the Perlite.
S6: They're gonna get plenty of water.
I: Why's that?
S6: Because the Perlite holds a lot of water. The light's gonna make it grow a lot 'cause it's working with the Perlite.
I: Do you think there's going to be a difference in the light and dark ones just like in the soil?
S6: Yeah! Well, not as much. Not as much.
I: Why not as much?
S6: The soil, uhh ..., the other two were just in the soil. They're both getting a lot more water.
I: Do you think water is going to make a difference?
S6: Well, not so much water. The light ... (pause)
I: What about the plant getting food in the Perlite? Is it different from the soil?
S6: I don't think the food ... I don't think the plant gets its food from the Perlite. Like trees, they produce oxygen. We produce carbon dioxide. I think the carbon dioxide might be a kind of food for them.
I: Can you show that in your illustration?
S6: You want us to show how it's getting its food?
I: Yes!

It was noticeable that S6's plant in the Perlite and darkness (Illustration 7) was better off than its soil counterpart in Illustration 6. Even though she seemed to perceive a definite source of food for the plant, she was not against being an eclectic when faced with a controversy about any one stated source. She was, however, beginning to become aware of her concept of how a plant obtains food to maintain its life. This may have been her first encounter with some of the conflicts she was going to face as she pursued this topic further.

Student S9 indicated on the pretest that food for plants was water, fertilizer, and "other stuff". He felt that roots were like mouths and consumed "rain, water and stuff from people". In spite of this, his illustrations for the first three days did not indicate where food for the plant
was coming from. He had to be prompted at the end of the first day to indicate the light that he spoke about on the pretest (Illustration 8). His predictions about the differences between plants and seeds rooted in soil and grown in light and dark (Illustrations 8 & 9), and the plants rooted in perlite (Illustration 10) all failed to indicate any source of food. Illustrations 8 and 9 indicated water for the plant in soil and rain for the Perlite plants that were in the light. This supported his pretest statements. However, contrary to his pretest statements, he indicated that plants in darkness would grow a little.

Similar to S2, his Perlite plants in darkness were thought to do better than the soil plants in darkness. On the second day, S9 mentioned in his journal that seeds need "sunlight, minerals, vitamins, water, and food", to sprout.

According to S9, the key elements for the plant to grow and prosper seemed to be the interaction between light, water, and the soil or other media. However, even though he spoke of food on the pretest and in his journal, he never illustrated food or captioned a reference to it on his first three drawing tasks. At best, he implied that water and sunlight were significant in Illustration 10 when he suggested that without sunlight for a period of time, the plants did not absorb water.

On the pretest, S2 also compared the plant's roots to an animal mouth. She perceived the plant to have a digestive process and that water and minerals were taken out of the soil for food that the plant needed. Soil was
Illustration 9
the substance that was rich in nutrients and provided the nourishment. Sunlight provided "growth support and dried up excess water". On the first day, her journal indicated that, "The things that help a plant grow and live are light, moisture, air to breathe, nutrients such as soil or plant food. My plant in the light will grow better. It will get extra nutrients that my dark plant will not get." Her picture for that day (Illustration 11) indicated that the plant in the light would use up some of the moisture and might be slightly better than the dark plant because it was "changing rapidly". The dark plant did prosper but was not using up as much moisture. This meant it was not getting sufficient nourishment. Illustrating the source of food was not of great concern to her at this point. She illustrated all of her earlier mentioned components necessary plant growth and was doing her best to illustrate the ambiguous relationship between moisture and light for nutrition. Even her picture on the second day (Illustration 12) that depicted the transition from seed to plant showed that moisture had to evaporate for the plant to be nourished. The seedling in light was illustrated to be larger and more robust.

How the plant actually got food and what the interaction among the environmental factors might have been was more obvious during the conversation between S2 and the teacher on the second day of activity.
Illustration 11
I: Do you think this seed needs food like the plant does?
S2: You have to feed and water it.
I: Remember, though, that we said water is not food.
S2: I think it kinda comes with food inside itself. Our plant grew 1 ¼ inches since yesterday.
I: What caused that to happen?
S2: Light.
I: In what sort of way... (pause) Can you explain that a little more?
S2: Ahh... (pause). No. I'm not sure.
I: Is light alone enough for the plant to grow?
S2: No. You need food and light and water.
I: So, how is the plant getting its food?
S2: By the soil and everything.
I: Do you think the food is coming from the soil?
S2: ... and the water and the light.
I: If you think the food comes from the soil, how does it get into the plant?
S2: Like when we drink water, the plant does the same thing. The roots.
I: How’s the little seed going to get food?
S2: It’ll grow roots. There are little holes in it.

In spite of her careful explanation of how plants obtained food, S2 didn’t care to illustrate the source of food at this time. Although she stated to the teacher that food, light, and water were necessary for growth, her dark plants (Illustration 12) used atmosphere, air, and moisture for some limited growth. Excess water seemed to limit growth. S2 didn’t seem to have a conceptual referent for a plant’s food. She couldn’t produce a graphic image of her rhetoric.

**Analysis of Data From Week Two**

Over the fourth, fifth, and sixth days, the students observed the plants that they had made earlier predictions about and entered their comments in their journals. They illustrated their new observations and then drew a new model of a plant based upon their perceived differences between what they had predicted and what actually occurred in the controlled situations. These sets
Set B1: Light

Observed: 10-7-93

Prediction: 10-13-93

Observed: 10-7-93

Prediction: 10-13-93

Illustration 12
of observed plants were subjected to light and dark environments. The comparison of their predictions to their observations of the plants was intended to encourage the students to provide some rationale for any differences that were observed. Awareness of these differences was illustrated by students’ changes in earlier models. The teachers role was to facilitate drawing tasks that would illustrate a rationale for each of the changes in the student’s model. During the dialogue with students over the next three days, it was reaffirmed that light was the experimental variable in each of the three sets of plants.

On the fifth day of activity, the children tested leaves from plants that had been exposed to light and those that were restricted from light. Up until now, the children were made aware of the things not considered to be food for a plant. Using glucose sensitive paper strips, it was expected that most of the children would reasonably perceive, as S2 did, that "leaves that were green from light certainly had more glucose in them than the yellow [dark] ones." This was supposed to provide them with some idea of the specific effect that light had on plants. Up until now, they were comfortable with the thought that food was somehow ingested into the plant and light somehow just made the plant healthier. On the fifth day of activities, and after the glucose test on the leaves, the teacher specifically facilitated the children’s activities in order to link sunlight to sugar used for food for the plant. They were beginning to realize that the sun was associated with glucose sugar that the plant used for
food. However, they still weren't comfortable with the idea that the plant’s food did not come from somewhere in the soil or perlite. The goal of the dialogue with the children was to help them deduce that the plant must somehow be making food within itself. At the end of the sixth day of activity, the teacher noted that some students were beginning to figure out that plants must come equipped with food because they don’t seem to be able to get it from anywhere else.

It was apparent from her drawings on the seventh day of activity (Illustration 13) that S6 had been impressed with the glucose tests. She noted that there was "lots of glucose" in the light plant. Based upon her comparison of the observed plant, the predictions from the first day, and the glucose tests, her new model indicated that the food for a plant now was light and glucose even though the light still kept the plant from getting soggy. The illustration also indicated that food seemed to form near the roots. Soil now seemed to be considered a medium that provided the water and other components to make glucose. Instead of soil being a type of food now, it seemed to be perceived as a source of components that the plant used for food. According to S6, "light travels to the roots and leaves to keep the plant from getting soggy" and the roots still brought the plant what it needed. How the light made glucose and what the components were was still not appropriately specified. The teacher’s conversation with S6 indicated the subtle confusion about where the
food for the plant came from even though it was not explicit on the drawing.

The arrow pointing toward the roots from her caption "food=light + glucose" implies food being drawn into the roots.

I: Let's see what you have. What did you draw today?
S6: O.K. I drew the plant and I drew the sun going into the plant.
I: Where?
S6: Right here.
I: I can't tell if its going into the soil or what?
S6: Yeah, it's going up into the soil.
I: What do the leaves do for the plant?
S6: They help bring the air and carbon dioxide down into the plant to help it grow, and uhhh ..., I got the water and stuff, ... if you mix it all together, uhhh, ... and when it does that, it can make sugar for....

At this point, S6 seemed to feel pressured into stating where the food was coming from and it was obvious that she was not comfortable with the process. It seemed that it would have been more comfortable for her to just be able to accept light and water as somehow being responsible for glucose without her being responsible for explication. It was a reasonable position for her to take. However, the teacher continued to probe for an explanation.

I: Where does it get its sugar from? Does it have to suck it in from the roots or is it already in the plant?
S6: Uhh ... the plant has to suck it up ... (pause)
I: What if I told you that the plant makes food inside of the plant? Can you re-think that? What if I told you it can't get food through the roots? Think about that.

More examinations, comparisons, and thought by S6 didn't seem to change her conception of a plant's life activities. She made no mention of food on her plant model for the 8th day of activities (Illustration 14). On the ninth day (Illustration 15), she labeled "new food" on the bottom frame. She was beginning to focus on light, carbon dioxide, water, and minerals as components that seemed necessary for the plant. Root media was no longer a
significant issue. On the 4th day of activity, her journal suggested that she
was beginning to see certain components necessary for food instead of food
being any one substance taken into the plant. One response in her journal
stated that "The things plants need to make food are light and water". Her
pictures for the sixth, seventh, and eighth days (Illustrations 13, 14, and 15),
suggest that light and water turn into food in the root media and must be
sucked in by the roots. A heavy dark line in Illustration 14 depicts sun going
into the soil to the roots that "absorb and carry".

S9 did not seem to be making any big discoveries about where the food
for the plant was coming from either. When the teacher observed his plant
model on the fourth day of activity (Illustration 16), he only seemed impressed
that plants in light were more prosperous than those in dark. He did not seem
totally convinced that light was the critical variable, however. According to
his journal, his plants had performed as he had predicted and "Plants don’t
need light to grow because light helps but it [the plant] does not need it to
grow because our plant in the dark grew." He was still trying to avoid
indicating a source of food for the plant.

I: Let’s see what you drew. I still don’t see where your food’s coming from.
Show me.
S9: Ummm, it’s coming from ... like the light.
I: O.K.. Write the word “food” wherever you need to.

At that point, S9 added rain, light, and water as a source of food on
Illustration 16. However, that seemed to be an afterthought because any
indication of a food source was avoided over the next two days. There were
Illustration 14
Illustration 15
indications that he was developing a new model at this time. The teacher asked provocative questions about his new model, as indicated on Illustration 16, and was also looking for any evidence that some of the new glucose test data might be incorporated into the new model.

I: Water, light, light, ... (pause). Where is it getting its food from?
S9: The soil right here (Illustration 17).
I: O.K., then what does the light have to do with it.
S9: It helps it get, ... It, it ... it makes it turn green and stuff.
I: I thought that the food was sugar.
S9: Oh! (pause)
I: Isn’t that what we mentioned earlier, "Food is sugar"? Think about that. Where would it get its food from? If a plant in the dark has no sugar, and a plant in the light has sugar, then light must have something to do with sugar, humm?
S9: I guess so.

He was certainly not convinced. His model on the sixth day (Illustration 18) indicated little change from the day before and any indication of food was absent. He stated in his journal that, "The things that plants need to make food are sun, light, and air. Plants do need light to grow because it’s food to them and they need it." He was not convinced about how that occurred and apparently did not feel comfortable enough to actually illustrate how it was happening. Words are easy to slip into a phrase that might spark an image in someone’s head. However, pictures are difficult to illustrate using meaningless phrases to guide the illustration. S9 needed more time to play with the notion of sugar as food for plants.

The plant that S2 drew on the fourth day of activity (Illustration 19), or her new model, indicated moisture as food for the plant and that light was
Illustration 16
Illustration 17
"helping the plant to grow healthy." The light helped the plant to grow healthy and the stems were healthy because they had light. She also stated that the dark plants had yellow leaves and unhealthy white stems because the plant does not have nourishment. Ordinarily, this is a necessary link to begin to conceptualize photosynthesis. However, S2 had not changed her concept of light evaporating the moisture so that food could be concentrated for the plant. Her journal did state that plants needed light to grow because light had nutrients that kept the leaves green.

[Dark and light plants refer to those kept, respectively, in dark and light conditions]

I: You show atmosphere, soil, ... O. K., what does the soil do? (Illustration 19).
S2: Ummm, the soil is something for the plants to grow. It's a bed of nutrients, sort of, ... and ... (pause).
I: What kind of nutrients?
S2: Ummm, it's getting ... (pause) ... nourishments.
I: And did you notice a difference between the light and the dark, Uhhh, ... did you ...?
S2: The leaves on the dark plant, ummmm are not ... and the stems are not very healthy.
I: Why not?
S2: Because they need light to strengthen them and keep healthy.
I: What does the dark leaf have that the light leaf doesn't? What is it that the yellow leaf doesn't have?
S2: It doesn't have green, and a plant needs to have green to have to be healthy and to live and grow.

Apparently, the glucose test didn't make a big impression on her either. The new plant model for the next day (Illustration 20) did not include glucose or sugar being manufactured in the plant. She was still concerned about the effect of moisture. If moisture remained, the plant was not eating. She was at least aware of the sugar test. However, she probably had not made the links necessary to incorporate this concept into her drawing because she might not have found it to be valid.
Illustration 18
Illustration 19
I: Tell me what you learned from your observations on your sugar test yesterday.
S2: Yesterday ...(pause) there was not so much sugar in the dark plant as there was in the light plant.
I: So, which one had more sugar?
S2: The light plant had more sugar than the dark plant.
I: O.K. so how do you think a plant gets its food?
S2: From the light ... from the light and water and from the soil. (pause) The one in the light is going to be a healthier plant than the one in the dark. The dark one didn't get all the nutrients.
I: Do you think the sunlight has nutrients that it gives the plant?
S2: (pause)

S2 perceived that healthy plants are green and that light, soil, and water account for it. To her, there was an interaction between those three variables whether or not she believed in sugar as food. Her model said that there was some ambiguous relationship between the light, water, and soil. Somehow, these must use water to become food, of some sort, for the plant. Basically, this was not a troublesome model to work with.

At this point, most of the students had developed an awareness of the fact that a plant needed food and that there were specific components from which the plant might even produce this food. They were also becoming aware that the plant needed food for some sort of energy and that food probably wasn't actually eaten by the plant as they knew eating to be done. This awareness seemed to have developed a sensitivity within each student so that they were more critical of information presented to them and would consider any data about a plant as long as it might fit with their developing model of the way that a plant obtains food energy. These models of the students seemed a little less ambiguous now than they were before.
B2 New plant model for 10-13-93

5 Light

There is a lot of bean has not grown.

moisture

air

soil

52

Dark air 10-13-93

Prediction from 10-7

there is no hard.

any moist.

leaves have been turning yellow.

stem not a healthy plant

air

plant

10-13-93

air

roots

moist.
Analysis of Data From Weeks Three, Four, and Five

At the beginning of the third week, the children began their activities by examining their plants that were rooted in Perlite with minerals and the plants growing in potting soil. The experimental variable for these two sets of plants was now root media. The teacher’s role was to facilitate the students’ consideration of what they had drawn whenever it didn’t seem to agree with what the actual plant was observed to do. Light as a variable had been examined and their awareness of its influence was now more concrete. Sugar would probably become more significant when they became certain that food was not coming from the soil.

At the beginning of this third week, the students were provided with access to a plant model that depicted how a plant obtains food. This model was illustrated on the chalk board and provided the students with resource data to consider while they were working with their models. The resource model indicated that minerals dissolved in water in the root media were absorbed by the roots and transported up to the leaves. The sun energized the chlorophyll in the leaves which facilitated a chemical reaction to occur. The reaction utilized water and carbon dioxide to produce glucose sugar which was used by the plant as food energy. Many of the children were receptive to the information since they were already aware that there were significant processes occurring that they were not capable of discovering by themselves.
Some of the children considered this new process reasonable since it did seem to correspond to much of what they had been experiencing with their plants. Thus far, however, no resource data were used in any of the children's drawing tasks until the interviews seemed to indicate some evidence that the children had been able to accommodate to the resource data.

Piaget indicated that some children relate to certain scientific concepts in terms of causality. "He [Piaget] concluded that to 'know' the causal nature of these concepts, the knower must be active (both mentally and physically) in interacting with the 'causal events', and gradually become aware of the processes involved in causality. Knowledge is not simple reflection!" (Good, et al., 1978, p. 691). Had the children been provided only with good demonstrations and been asked to consider the outcome, some doubt exists that they would have attained a readiness to reconstruct any of their previous concepts about plants. However, even though these children were motivated by aspects of causality, they were not quite ready to fully accept the provided model as the link between their prior knowledge and their current experiences. Data provided to students up to this point in the form of test activities and resources on the board apparently had not made a significant impact on their concepts as indicated by their illustrations. Not very many pictures were immediately indicating acceptance of this model. Some children did provide discourse that reflected some aspects of the provided plant model. However,
it seemed that the children were quicker to orally depict something than they were able to engage in a drawing task that represented their oral depiction. The connotation of a word carries many vague details which are implied by the word even if not fully understood by the individual speaker.

The second and last day of this third week continued with the students trying to accurately structure their illustrations to agree with their verbal models. The activity that was facilitated by the teacher and by peers now seemed to be focused on the leaf of the plant. More attention was being paid to the sunlight’s effect on the plant than before. There were still some children who were showing the light energy somehow interacting with food already present in the leaves. In some cases, food activity was still having to be initiated in the soil before being brought back up to the leaf. But, in all cases now, the plant was active in synthesizing food. Sometimes, the process was ambiguous and occurring in the soil next to the roots. The plant was becoming an active producer rather than a passive receiver.

During the last two days of intensive interaction between the teacher and the student, the students compared their Perlite plants, with and without added minerals, to one of the plants grown in soil. By this time, most of the children were fairly certain that sunlight had a definite relationship to the food process of plants, but they were still unsure what role the root media played. The major problem inferred from the illustrated models was that some
children still indicated a correct process occurring in the wrong place. In many cases, the soil was where the sugar was being made by the plant and then brought to the leaf from the processes in the soil. On the eleventh day of activities the children examined their earlier illustrated models, especially the three from the week before, and attempted to consolidate them into one model that represented their concept of how a plant obtains food. The teacher’s role was to facilitate a consolidation of the plant models without any contradictions. An oral depiction that differed from the illustrated model was not acceptable.

Basically, the students were asked to look at their progression of models which ranged from plants in soil and perlite media, both light and dark environments, seedlings which sprouted in light and dark, and the comparison of plants in media with both natural and added minerals to those with no minerals. They consolidated these into one model that represented how they now perceived a plant to obtain food energy.

In Illustration 21, S6’s plant in soil seems to get food from the soil as well as that which is "mixed up by the light". The Perlite plant, however, suggests a nearly appropriate model. Illustration 22, however, shows a plant getting food from the root media as well as glucose being produced in an unspecified place by "light [mixing] everything together". A conversation
between the teacher and S6 on the eighth day was initiated by her depiction of her new model of a plant in Illustration 22.

I: Show me how your new plant gets food.
S6: It gets food from CO₂, sugar, water, and sucks it up.
I: Is the food getting sucked up into the leaves?
S6: Well, it really doesn't suck the sugar up.
I: Tell me what you do mean.
S6: The food is made up there. [Points to Illustration 22]
I: In the leaf?
S6: Yeah.
I: What is the glucose, or sugar?
S6: Food.
I: Let's see. The CO₂ is going into the leaves, the light is going into the leaves, the water... and what else is coming out of the soil?
S6: Water and minerals.

Although S6 said that the sugar wasn't getting sucked up to the leaves, Illustration 22 indicates that food was coming out of the soil. However, on the ninth day, when the three models were consolidated to indicate how the child's current model functioned, each of the frames in Illustration 23 indicated that the roots and media were primarily to access components of food and transport the material upward. The light and carbon dioxide utilized the water and minerals to make food in the leaf. An important indication in Illustration 23 was that the Perlite plant without minerals was illustrated as being unable to manufacture food. There seemed to be a realization that food was made in the plant as a result of components being brought into by the plant. Without these, the plant could not make food. The final model on the eleventh day (Illustration 24) explicitly illustrated that the process of making food occurred in the leaves.
Illustration 22
The journal entry written by S9 on the seventh day stated that, "Plants get their food from light, water, minerals, carbon dioxide, put together = sugar for food." The next day he stated that the big difference between soil and Perlite for plants was the mineral content and that plants made their food as stated above. Even on the eleventh day, he stated in his journal that his current model of plants was now different because he was "sure that the food is not mixed in the soil" as he thought before. Looking at his illustrated plants on the seventh day (Illustration 25), it seemed apparent that the two plants were functioning the same even though one was in Perlite and the other was in soil. Although he didn’t indicate where the food was, it certainly did not appear to be coming intact from the soil and light did appear to influence the leaves of the plant. Soil and Perlite were not shown to be entering the roots. However, any notation concerning food or its origin was absent. The same was true for the picture on the eighth day (Illustration 26). A comparison of the three plants on the ninth day (Illustration 27) still didn’t indicate any mention of food. At least the importance of minerals was recognized even if the viewer must guess why they are important. The light that had earlier made its way into the soil and/or roots (Illustration 27) became significant in S9’s Illustration 28 on the eleventh day. His reluctance to indicate the final process of food in the drawing was sensed during the conversation between S9 and the teacher.
Illustration 23
I: What's happening down here? [Illustration 27]
S9: O.K. The soil has minerals and then ... and then when water goes into the soil
and then the minerals get into the water and the roots suck it up.
I: Where do the water and minerals go?
S9: To the leaves.
I: What happens when the water and minerals get up into the leaves?
S9: The light and uhhh ..., the light and uhhh ... and CO₂ and the water and stuff,
... mix together and make sugar.
I: What does the plant use the sugar for?
S9: They eat it. They ... like, they get nutrients from it, they get energy from it.
They use it for energy.

There was uncertainty about the place where the food was processed.

It seemed easier to talk about it than to illustrate it. Illustrating meant that he
would have to be a great deal more specific. It either looks like it agrees with
someone’s concept or it doesn’t. It is hard to disguise one’s meaning with an
illustration from these drawing tasks. Although S9 was telling his teacher
about food produced in the leaves, he seemed more comfortable (Illustration
28) maintaining the idea that light goes into the roots and does its work there.
Sugar was depicted in the root. The old model was changing, however, even
though it was not a radical change.

Even though some of these students didn’t have a precise model yet,
they had a more appropriate model than they had before. It seemed that when
they were unsure of something, they didn’t illustrate it. They did, however,
manage to verbally articulate some things they were unsure of. From S9’s
drawing for the eleventh day (Illustration 28), it was apparent that the food
making process was still going to occur in the roots even though it did move
up to the top of the roots. So, even though S9 was able to articulate the
photosynthetic leaf in discourse, he was slow to illustrate the same concept
Illustration 26
Illustration 27

On 10/26/12, illustration 27 shows a plant with the following components:

- **Light**
- **Soil**
- **Roots**
- **Water**
- **Air**

The plant has the word "Perfect." It is noted that the plant started to grow but ran out of minerals and died. It is also mentioned, "No minerals at all cannot grow."
with drawing tasks. Most of the other children were now indicating that food was produced in the plant by a process that involved sunlight and other components to synthesize sugar.

When S2 examined the plants in soil and perlite, her conclusions about activity that related to food for these plants were summarized by her drawings on the seventh day (Illustration 29). Although she captioned one frame to state that "Food is coming from sun and min. [mineraled] water", and her journal for that day stated that, "Plants get their food from CO₂, air that has mineraled water, soil, and light", her teacher was unable to discern a process from her illustrations that depicted how food got inside the plant.

I: Explain to me where your plant is getting its food from.
S2: O.K. The roots suck all the water and the minerals and sends it up to the leaves and the CO₂ goes in the leaves and it all mixes up together and makes glucose and, uhhh, ..... 
I: Does that happen in the roots or the leaves, the soil, or where?
S2: The leaves.

Her drawings on the next day (Illustration 30) depict plants in Perlite. The captions indicate that soil and moisture help minerals get to the leaf. That seems like a significant indication of movement away from a plant using soil for food. However, her Perlite plant in the right frame listed Perlite as an artificial plant food and that the roots were sending nourishment to the stems and leaves and other indications that food was waiting to get into the roots. Finally, on the eleventh day (Illustration 31), she consolidated all of her ideas about plants into one model that she and her teacher discussed.
Illustration 29
I: [Her name] let's see what you have drawn.
S2: Mine has pictures that show the sun, uhh...where the sun is.
I: Does the sun go down into the soil or does it do its work in the leaf?
S2: UV rays, ...well, ...I think the rays are captured by the leaf and the CO₂.
I: What happens ... (pause). What happens when the rays enter the leaf?
S2: Everything gets mixed up by the UV rays and makes glucose ... ummm ... it's sort of food.
I: Well, what's happening in the soil here [pointing to the illustration] ... near the roots?
S2: Uhhh ... food, ...uhhh ... well, nourishment and stuff gather in the roots ... uhhh, and this, minerals and water, kinda like food, go up to the leaves to mix with UV rays to make glucose. You need CO₂ too. CO₂ is nourishment ... I mean glucose is nourishment for the plant.

Apparently, the curved arrow going from one of the little suns into the soil made the teacher wonder about the role of sunlight. A caption for the plant states, "Minerals and water make food that goes into leaf and then CO₂ makes food in the leaves". However, these captioned messages of S2 are not apparent in her drawings even though her journal entry on the eleventh day states that "Plants get their nourishment from the sun, air, minerals and H₂O. This nourishment is prepared in the leaves." Also, the way S2 and others talk about "a sorta' food" makes it seem like they might be referring to a precursor to food even if it is not the final product. When the teacher tried to discuss this topic on several occasions, the discussions were clouded with ambivalence and confusion. The concept of food for a plant was still a mystery in some cases.

Although it was apparent that these students' oral and written presentations differed somewhat from their illustrations, the relationship between the two were closer toward the end of the activities than early during
Illustration 31

10-28-93
OCTOBER 28, 1993

MINERALS
WATER
MOISTURE

MAKE FOOD
THAT GOES
INTO LEAF
AND THEN
CO2 MAKES F0
IN THE LEAVES

PLANT
FAIR
NEEDS
MINERALS

MOISTURE
SUNLIGHT

Illustration 31
the project. Keeping this in mind, it is interesting and insightful to look at a summary of their posttest and delayed posttest answers that explain how they believed plants obtain food energy.

S6 stated on the posttest and delayed posttest that food for plants was glucose made in the leaves when water, carbon dioxide, and minerals were put together by sunlight. Roots sent water and minerals up to the leaves. Leaves made food and sunlight provided the energy to mix everything. S9 stated that food for plants was sugar or glucose made from water, carbon dioxide, minerals and sunlight that leaves got and made food. The soil provided minerals and water and sunlight provided energy to make the food. S2 stated that food for plants was the glucose made up of the water, carbon dioxide, and minerals. Roots absorbed the minerals and water from the soil. Leaves made the food from those components and sunlight dried the stuff to make glucose. S2's ideas about the significance of the sun changing water concentrations in the plant persisted. However, the overall model about how plants got food is closer to an acceptable one now than it was at the beginning of the activities. Most students in the Experimental Treatment Group believed that food was energy for the plant and was synthesized in the plant by sunlight energy and other components taken into the plant.
Analysis of Student Interviews

The interviews with the twelve selected Experimental Treatment Group students were conducted on the twentieth day after the pretest. During the interviews, the students had access to an illustrated model of a plant similar in style to the ones that they had drawn (Appendix G). This model could be used by the students as a reference. The interviews were conducted individually in a private room. The students were advised by the researcher that the interviews would be recorded by him for records and later analysis. Excerpts from the recorded interviews with S2, S6, and S9 focused on how they believed plants obtained food. The researcher conducted the interviews and offered these students the opportunity to critique one of their earlier illustrated models during the interview. The following are excerpts from the interview between the researcher and S2.

I: If plants can't walk around, how do you think they get their food?
S2: (Pause) Uhhh... The water is coming down into the plant. Then, it sucks up the minerals, then goes up the stem up to the leaves. Then, the sun goes into it, ... the leaves and, ... and the CO₂ and, ... then they all mix up in the leaves. And, that's how it makes its food.
I: What is that food?
S2: What's it called? (pause) Glucose.
I: If there is no sunlight, how does a plant go about getting its food?
S2: Well, if they don't get it from the sun and they don't get it from any light, then they really can't produce food. That's all.
I: Do you remember keeping plants out of the light?
S2: They turned yellow and plants are supposed to be green. And when we did the test with the piece of paper, ummm, the yellow ones, the piece of paper stayed yellow and the ones that were green, they turned green.
I: What did that tell you?
S2: The green plants had more sugar, glucose, and the yellow ones, glucose was not strong. It wasn't.
I: Why was there a difference in the two?
S2: Ummm, 'cause, because the ones, I think that if it's in the light, then the sugar, ummm (pause).
I: Where was the one in the dark getting its food from?
S2: None, really.
I: On this drawing that you did on 10/28 [Illustration 31], is there anything that you'd want to change?
S2: I think if I could draw it again, ummm, I'd draw it with someone sprinkling the plant with water, and then the minerals down here, and then they mix together, ummm, in the leaf, and then mixing together to make glucose.
I: But, I see minerals down here in the drawing. And, you say that they mix with water to make food for the leaf.
S2: (pause) I think it was ... I thought it was a kinda food ... The stuff goes to the leaf to become food. Glucose. The light does it. The leaf gets the CO₂ and the light makes food when the leaf is green, but it can't make it without water and minerals, you see.

There were differences between her oral descriptions and those produced by the drawing tasks prior to the interview (Illustration 31). However, there was a comfortable level of consistency in the dialogue with S2 during the interview. Perhaps it was the interaction with peers when the group models and the community model (Appendix E) were developed. The group models were produced by four students in each group. Their collaboration produced one model that represented the consensus of the group. Anyone who was not satisfied with the group model could submit a model representing their concept. Aikenhead (1989) pointed out the effectiveness of group decision as probably one factor in initiating conceptual change. From what the researcher observed, this task was taken seriously. Uncertainties were amicably resolved within the group. The drawing style of S2 is apparent in her group picture (Illustration 32) The difference between Illustration 31 and Illustration 32 correspond to S2's dialogue during the interview. Although the specific details of photosynthesis seem a little unclear and even unimportant to her, she is aware that food for a plant is synthesized inside of
the plant from components exogenous to the plant and light is a key factor.

The plant cannot be fed.

The next discussion was with S6.

I: If plants can't move around, how do they go about getting their food?
S6: They just, uhhh, they just take everything that’s around it, they put it to the leaf and the leaf mixes everything.
I: Mixes everything ...?
S6: Mixes. Ummm, light, and CO₂, and water, and minerals.
I: What are some of the things that a plant uses to make food?
S6: Ummm ... light, and CO₂, and water, and minerals. Ummm ... it’s glucose.
I: What is glucose?
S6: Sugar.
I: Does the plant eat the glucose?
S6: Ummm, no. It uses it for energy.
I: Where does it get this glucose from?
S6: (pause) Ummm... (long pause) The leaf.
I: Is it already in the leaf?
S6: It makes it in the leaf.
I: How else does a plant get its food?
S6: (long pause)
I: What about plant food or glucose on the ground?
S6: No. It needs to make its own food.
I: And if it doesn’t make its own food ...?
S6: It’ll die.
I: Did you have any of your plants in class die?
S6: Uh huh.
I: What made them die?
S6: Well, if it didn’t have one or two or any of the things that it needed to make food, then it didn’t have any energy to grow. It just died.
I: What do plants use food for?
S6: To grow and to stay alive. Energy.
I: Where do plants get their energy from?
S6: The glucose.
I: The plant you drew on the 28th [Illustration 24], ... . What would you change?
S6: I ... (long pause). I think it’s the way it is (pause).
I: Are you comfortable with it?
S6: Yes. (pause) Look at how much the leaf does!

S6 seemed comfortable with her concept of how plants get food. Her references to the model, her discourse, and her model on the twenty-eighth (Illustration 24) were in correspondence with each other. She seemed quite surprised when she saw her drawing again and realized how much occurred in
Illustration 32
the leaf. The annotated illustration with activity vectors was dramatic. Her contribution to the group picture (Illustration 33) was apparent with the little faces blowing CO₂ and the expression, "Everything mixes in the leaves". The following statements are excerpts from the interview with S9 conducted by the researcher.

I: O.K. Well, with plants, you said they can only have what they need. (pause) How do they get what they need?
S9: (motioning to the model) Well, the light comes in, and that goes into the leaves. And then from the soil, they, ... they can get water and minerals, and then, the air goes in the leaves and it all, ... I mean it all, ... uhhh, ... the, ... the water and the minerals mix in the soil, kind of around the roots, and then it goes up to the leaves. It all mixes up in the leaves and makes glucose sugar.
I: Could I mix some glucose in water and pour it on the soil?
S9: Uhhh ... no. I don't think, ... cause it has to make it itself.
I: Where does it make that food?
S9: In the leaf.
I: Uhh... . (pause) What about if ... what about plants that are in the dark?
S9: Oh, if they don't get their light, they can't make their food.
I: Can't I feed them if they're in the dark?
S9: Uhhh, well ... you could .... no. They have to have light. You can put ... you can come from like a strong light or the sun. But, if you don't have light, they can't do it.
I: What happens to plants that aren't kept in the light?
S9: They, uhhh ... kinda lose their color and stuff because of chlorophyll or something like that and they ... they turn yellowish a lot.
I: What's wrong with that?
S9: Well, when they don't get light, uhhh, they don't get food.
I: (long pause) Look at that plant that you drew on the 28th [Illustration 28]. Just glancing at it, can you see if you'd change anything?
S9: Well, I'd ... I would ... 'cause I had ... the sugar is in the roots and I had water, air, and sugar mixed in the roots. I'd put, like the water and minerals ... are mixed right up in the roots. And then the mixed stuff goes up into the leaves and, ... and then the air and the leaves plus the light, ...and that makes the food right there. I'd put that instead. 'Cause for here, ... I have water, air, minerals mixed in the roots with sugar.
I: When did you change your mind on that?
S9: Uhhh, you mean .... Probably when I figured it out when ... when we did that big overhead thing. 'Cause, ummm, ... I mean, before we did that, uhhh, ... well I figured out that it was mixed in the leaves. Before that, ... I mean ... (long pause).
Examining Illustration 28, it certainly appears that S9 had conceptualized that a plant is autotrophic. His basic procedure, however, was incorrect. A comparison of Illustration 28 with the group picture he participated in (Illustration 34) suggests that his new idea about where the glucose was produced might very well have begun at that time. When everyone was participating in the community picture (Illustration 35), or the "big overhead thing", that activity was in correspondence with the group model and made an impression on him.
Illustration 34

Plant gets its food from CO₂, water, minerals, light.
Summary

Table 7 suggests that 50% of the children in the Experimental Treatment Group indicated on the delayed posttest that food provided energy for a plant. It was stated earlier that Roth and Anderson (1987) suggested a direct relationship between children’s concepts of food and their willingness to accommodate to a scientifically appropriate concept of photosynthesis. Although this project did not examine such correlations or causality, it does seem reasonable since the concept of photosynthesis does include the transfer of light energy to chemical energy in the form of glucose.

Table 7. Percentage of Experimental Treatment Group Students Who Indicated That Food Provides Energy for an Organism.

<table>
<thead>
<tr>
<th>Test</th>
<th>Pretest</th>
<th>Posttest</th>
<th>Delayed Posttest</th>
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<tbody>
<tr>
<td>%</td>
<td>25</td>
<td>63</td>
<td>50</td>
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</tbody>
</table>

Table 8. Percentage of Experimental Treatment Group Students Who Indicated That a Plant’s Food is Obtained Intact From the Soil or Dirt. There was no indication that the plant synthesized food.

<table>
<thead>
<tr>
<th>Test</th>
<th>Pretest</th>
<th>Posttest</th>
<th>Delayed Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>63</td>
<td>00</td>
<td>04</td>
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According to Table 8, only one of the Experimental Group Students, or 4%, indicated on the delayed posttest that a plant could obtain food intact from the soil. This corresponds to the dialogue between the teacher and
students toward the end of the project and from the interviews conducted by
the researcher. Not all of the students were accurately depicting where the
process of photosynthesis was occurring, but they certainly were indicating
that synthesis of food occurred in the plant when certain components were
present in lighted conditions. Table 9 indicates that 95% (column C) of the
Experimental Treatment Group students stated on the delayed posttest that a
plant’s only source of food was what it was able to synthesize.

Table 9. Percentage of Experimental Treatment Group Students Who
Indicated (A) That the Plant is Able to Synthesize Food and (B) Percentages
of the Same Group Represented by A Who Indicated That the Plant is Also
Able to Get Food Intact From the Soil. (C) Indicates Percentage of Students
Who Stated That a Plant’s Only Source of Food is What it Synthesizes.

<table>
<thead>
<tr>
<th>Test (% Experimental Group)</th>
<th>(A)</th>
<th>(B)</th>
<th>(C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>21</td>
<td>17</td>
<td>03</td>
</tr>
<tr>
<td>Posttest</td>
<td>98</td>
<td>00</td>
<td>98</td>
</tr>
<tr>
<td>Delayed Posttest</td>
<td>96</td>
<td>01</td>
<td>95</td>
</tr>
</tbody>
</table>

The interviews with the Experimental Treatment Group and the
Traditional Treatment Group that were conducted by the researcher near the
end of the project illustrated that the two groups were almost polarized on
their concept of how plants obtain food. Most children in the experimental
treatment indicated some appropriate changes in their ideas about how plants
obtain food while very few children in the traditional treatment indicated
appropriate changes. This is also suggested by the results on the delayed
posttests and Tables 4 through 9 that were discussed above. Analysis of these
data suggest that the experimental group teacher's facilitation of her students' activities that were guided by the use of their drawing tasks did effect more appropriate conceptual change about photosynthesis than the teacher using didactic instruction. Overall, a greater percentage of the children in the experimental treatment were in correspondence with the recommendations of *Benchmarks for Science Literacy* (AAAS, 1993) for students between grades two and eight.

How difficult it must be for a teacher to realize that lessons presented to a class in a clear, logical, and thorough manner could be so misconceived. Although a presentation might be appropriate to the presenter who has a logical and relevant view of the material and understands the basic concept related to the topic, this is not true for children who have well constructed misconceptions. It seems reasonable to suspect that the same effort and planning that was necessary to transition the Experimental Treatment Group from a concept of a "dirt-eating plant" to one that describes an autotrophic organism would have been necessary for the Traditional Treatment Group.
Summary and Conclusions

Overview

Research and classroom experiences indicate that many elementary school science students are not significantly affected by their classroom study of photosynthesis (Shuell, 1987; Champagne, et al., 1982; Kyle & Shymansky, 1989; Hills, 1989; Mintzes, et al., 1984; Roth & Anderson, 1987; Wandersee, 1983). Many of these students become sufficiently adept with the rhetoric related to the photosynthetic process of plants to enable them to engage in classroom discourse without ever communicating their experientially constructed understanding of how plants obtain food (Osborne, 1980; Watson & Konicek, 1990; Silver, 1981). This project illustrated that there can be a notable contrast between children’s conceptual models of how plants obtain food and their rhetorical implications. The discomforting aspect is that some learners seem to maintain this dichotomy of experiential knowledge and classroom knowledge as an appropriate circumstance of their formal education. This was evident by the efforts of the Traditional Treatment Group students to commit to memory whatever was necessary to satisfy the teacher. This was done without any objections to the obvious conflict with their prior beliefs. Indications of any metacognitive activity were not obvious to the researcher. Whenever a classroom doesn’t offer children a reasonable opportunity to reconstruct their ideas in ways that correspond to
appropriate scientific belief, this dichotomy seems essential for the learner's academic success. The learners perceive that their function is to properly "fill in the blanks" without question. Teachers responsible for this kind of environment should consider Littleford's (1989) feeling that, "Humans became humans when and only when they began to think and express themselves symbolically, not when they began to manipulate tools" (p. 22). Dialogue between these students and their teacher that was sustained by this kind of semantic facade instead of constructive communication did not engage these learners in the type of cognitive processing necessary to construct a more scientifically appropriate concept. Whenever structured rhetoric is an acceptable response to a teacher, reconstruction of concepts resulting from cognitive dissonance does not occur (Zibroski, 1989; Vygotsky, 1962). Selective assimilation of data by learners that supports their conceptual ecology instead of voluntarily engaging in cognitive conflict seems to be a reasonable recourse to cognitive dissonance.

This study illustrated that the pedagogy and activities in the Traditional Treatment Group classroom did not correspond to the tenets of conceptual change theories (Posner, et al., 1982; Sigel, 1984; Watson & Konicek, 1990; Osborne & Wittrock, 1983; Eaton, Anderson, & Smith, 1983). The implied rationale for the didactic methods was that logically presented data and appropriate activities are sufficient for a learner to accept the ideas involved in
the lesson in lieu of their prior ideas which should seem insufficient as a result of the teacher's logical presentation. However, the analysis of data indicated that it was common for these children to selectively accept only what was needed to support the integrity of their conceptual ecology in spite of the logic and validity of the presentations. The experimental treatment was based upon constructivist practices. The pedagogical strategy should consider what the learner already knows about the topic or, more broadly, how the learner’s framework related to the topic is structured (Anderson & Smith, 1987; Champagne, et al., 1982; Eaton, et al., 1983). For the Experimental Treatment Group, the strategy was based upon the idea that if the children's ideas about plants were in conflict with the appropriately scientific idea of photosynthesis, then changing their ideas to correspond to scientific orthodoxy would certainly require conceptual change practices. However, prior to challenging each child’s concept of plants, it was necessary to understand how each one conceptualized the construct of how plants obtain food. Without this knowledge, it was not possible to provide an experience that would challenge their prior experiences enough to effect conceptual change (Hills, 1989; Lorsbach & Tobin, 1992; Osborne, 1980; Gabel, 1994). Each child’s model of a plant had to be addressed so that it could be appropriately challenged by the outcome of real plants (Smith, et al., 1993; Roth & Anderson, 1987).

Communication with the children was necessary to determine their concept of how plants obtain food. The primary problem involved here was
that many of the children relied upon rhetorical statements to express themselves even when their conceptual model contrasted with their discourse. Prior experience indicated that verbal communication alone was not sufficient to do this. Based upon research that indicated that children's cognitive skills can be determined by both verbal and visual modes and that they can construct models to communicate visually even when they don't have the verbal or semantic capabilities, this researcher chose to use drawing tasks as one of the primary means of communicating with the child in order to illustrate their concepts of plants (Silver, 1981; Howe & Vasu, 1987, 1989; Curtis, 1988).

**Research Questions**

In order to compare pedagogy corresponding to a constructivist epistemology with the didactic methods corresponding to an objectivist epistemology, two primary questions guided the research. The first question asked if elementary-grade students who received instruction about photosynthesis might acquire and retain more knowledge when facilitated by teacher analysis of their drawing tasks than students who participated in didactic instruction. This question examined the amount of content knowledge acquired and retained by children subjected to each of two teaching strategies. The analysis of the research data indicated that there was a statistically significant difference between the scores of the two groups when measured at the posttest and the delayed posttest. This analysis measured the quantity of correct answers achieved by the students on these tests and did not try to
ascertain whether or not these answers reflected the children's concepts about how plants obtained food. The reason for this aspect of the research was to preempt the concern that constructivist pedagogy is not as effective as traditional methods when the amount of content is considered (Dreyfus, et al., 1990). The Experimental Treatment Group answered significantly more questions correctly than the Traditional Treatment Group indicating that they had acquired more content knowledge. There was no significance difference between the two groups when changes in scores were analyzed over time. The analysis indicates that there was no significant difference between the two groups in retention of acquired knowledge.

The second question addressed by the research activities sought to determine if elementary-grade teachers who were guided by students' drawing tasks that depicted their concepts of photosynthesis could effect more appropriate conceptual change than a teacher using didactic methods. This question looked at which of the two treatments would be more effective in enabling the children to change from a heterotrophic to an autotrophic model of plants. A qualitative analysis of students' responses collected from interviews with both groups and a comparative analysis of answers to questions provided by the three written tests that were administered did indicate that a more appropriate evolution of the concepts held by students from the Experimental Treatment Group were apparent than those of the Traditional Treatment Group. In the case of the Experimental Treatment
Group, the students' drawing tasks were assumed to represent their concept of plants and were used to guide the instruction and validate the discourse of the child. These drawing tasks also illustrated the sequence of each child's evolution of concept. As a result of the research analysis, a logical inference can be made that the students exposed to the experimental treatment were able to develop a more scientifically appropriate concept about how plants obtain food than the students in the traditional group.

Problems and Limitations

Initially, many of the children in the Experimental Treatment Group had difficulty trying to use drawing tasks to communicate their ideas. Using a sketch to express ideas about the complex process of photosynthesis was, in many ways, essentially the development of a composite sketch. As each child's ideas about plants changed, parts of the original sketch changed to reflect a new understanding of plants. Within three days of activity, the children began to develop a tacit understanding of how to communicate with drawings.

The nature of this project required several weeks of intense activity for the children of the Experimental Treatment Group to try to determine how a plant obtains food. Each child encountered a time when he or she temporarily lost interest in the project. But, working with peer groups and the daily intervention by the teacher was sufficient to steer the children back on task with a renewed interest. Of special interest was that none of the children
showed any indication of being able to produce a pretense of understanding with their drawing tasks equivalent to the semantic facade so easily fabricated with their classroom generated rhetoric.

As indicated above, teacher/student interaction, teacher analysis of learners' concepts, and teacher facilitation of the learner toward a concept that was in correspondence with scientific orthodoxy was critical for this conceptual change strategy (Posner, et al, 1982; Tomasini, 1990; Smith, 1983). Accordingly, content knowledge of the teacher was a significant factor (Lederman & Ziedler, 1987). But it can also be a limiting factor. When a teacher is not well informed about the topic being taught, guidance and analysis would almost certainly be limited. In addition to the appropriate content knowledge about the topic being taught, a classroom teacher would have to be willing to engage in the intense preparation and interaction with the students indicated by this project. The effectiveness of this interaction is also dependent upon the teacher's knowledge of some of the common misconceptions that students possess about the topic. Sometimes the indications that a student is misinformed are very subtle. Proper analysis requires integration of the teacher's content knowledge with knowledge of student misconceptions and ability to interact constructively with the students.

Conclusions

Words such as used for conceptual labels don't always identify a common concept. Yet, they are one of the basic units of communication
within the classroom. The influence of the spoken word in the classroom encourages children to become very strategic with semantics. Unfortunately, their strategies can work against the very resource for which they were intended. The object or event that any two people are experiencing might have some basic similarities to each party. However, how each party perceives the experience depends upon many cognitive variables.

Pedagogy used in many traditional classrooms seems to correspond to an epistemology that supports cognitive conformity among the learners. The unreality of this is that each child's perception is based upon his or her individual experiences and cognitive characteristics. Efforts to get children to conform to pedagogy rather than teachers addressing their cognitive idiosyncrasies encourages the children to protect the integrity of their individual conceptual frameworks since this is the basic unit of their negotiation with the environment. Their ideas of how the world works is not easily changed until something significant indicates that their interpretation might be flawed. How a teacher handles this problem will usually be determined by the mode of communication between the teacher and each individual student. Unless the teacher addresses each child's ideas about the topic being taught and provides some opportunity for the child to restructure his/her idea when necessary, analysis of a child's concepts related to the topic being taught will, more than likely, be limited to inferences made from scores
on quantitative tests. If these tests are not designed to examine a child’s conceptual knowledge about a topic, the inferences made might not be valid.

Implications and Recommendations

Hashweh (1988) noted that tenacious preconceptions of children are probably the result of pedagogy that employs logical dogma rather than some conceptual change strategy. A child’s normal cognitive processing constructs ideas that are usually unaffected by a dogmatic pedagogy (London, 1988). Children might provide rhetoric that will agree with classroom dogma in order to protect their academic status in the classroom. However, this usually does not influence their real ideas very much or for very long. This study noted what many other researchers have found; there are many misconceptions of how plants obtain food (Wandersee, 1983; Roth & Anderson, 1987; Mintzes, et al, 1984). Of further significance is the assortment of ideas held in one elementary-grade classroom and the diversity of change in these children’s ideas over a period of time. These considerations seem to suggest the futility of trying to select any one classroom presentation that might effectively attend to this degree of conceptual diversity

Conceptual change strategies employed in a classroom require that a teacher be aware of each child’s prior conceptions (Shuell, 1987; Sigel, 1984; Osborne & Wittrock, 1983). When they are found to be inaccurate, challenges must be provided. Activities that confront the child’s ability to explain things on the basis of his or her present conceptual ecology and
facilitation toward the selection of an appropriate one are requirements. As this project indicated, a series of challenges are necessary to facilitate the evolution of ideas involved in conceptual change. There were no indications during the study that any child was significantly influenced to change concepts on the basis of dogma or that any new ideas were the result of a single reconstruction.

The key to effectively using conceptual change strategies in the classroom is communication with learners. This communication has to be able to generate dialogue that will accurately illustrate the child’s ideas about the topic. It was noted on many occasions during the classroom activities and the interviews that the children’s discourse was able to obscure their real ideas about plants because they had developed a strategy that involved semantic facades. The series of line drawings that the children used to depict their evolving concepts during the phases of instruction seemed effective for interpreting their real ideas. Not only was the strategy able to help the teacher visualize the children’s concepts, it served as a metacognitive tool for the children. The results of this research implies that classroom science teachers consider communication strategies that enable them to discern students’ concepts related to the topic being addressed in the classroom.

A starting point for a teacher preparing to use children’s drawing tasks as one medium for communication of their ideas about a particular topic should be a simple, captioned drawing by the teacher. This would give the
teacher some idea of the scope of the task and what type of starter sheet to provide students with (See Appendix A). The starter sheets maintain some degree of congruence to what would certainly be a myriad of styles and sizes of illustrations. They also serve as good models to demonstrate to children how to express themselves with illustrations and words. The children involved in the experimental treatment of this project were encouraged to use arrows and blurbs or other enclosures around their comments. In addition to segregating their statements, this style of drawing implied that ideas should be expressed with as few words as possible. A physically illustrated interpretation of some of the verbally expressed conceptual labels is a primary goal of this strategy.

The variety of students' illustrations in the preceding chapter depict the degree of congruency that can be achieved when starter pictures and modeling are provided to the children. Illustrations 10 and 24 depict "clean" illustrations that can be analyzed by the concentration of and direction of the arrows in conjunction of the encircled terms defining the activity implied by the arrows. A teacher can quickly discern from viewing Illustration 10 that the student conceptualizes the soil to be one of the most critical providers for the plant. Just the opposite is implied by Illustration 24. These kinds of indications are good stimuli for dialogue between the teacher and student.

One idea that surfaced toward the end of the classroom activities was that of the teacher collecting children's drawings at the end of each class
period. The teacher could then study the children’s illustrations produced for that day, compare them to previous illustrations and the children’s journal entries and then provide comments to the children by using post-it-type messages attached to the latest illustrations. This would give the teacher more time for careful consideration of the work being analyzed and more time for the children to carefully consider the teacher’s comments. This needs to be considered as a possible way to improve communication between the teacher and each child.

More dialogue between the teacher and each child will be necessary to determine why some children do not even attempt to include certain ideas in their illustrations when they are uncertain of how the idea corresponds to what they already know. One example is when some children in this study would not illustrate how plants obtained food. They were unsure of their earlier ideas and could not conceptualize photosynthesis. One example of this type of behavior was noticeable when some of the children in the experimental group would not illustrate a source of food for the plant. It seems that they were convinced that the plant was not getting food from the soil and were not yet comfortable with the idea of the plant synthesizing food in the leaves. None of the children had a problem with orally providing rhetoric to talk about photosynthesis even though they did not believe or understand it. More study is needed to determine why comparable behavior does not occur when children are illustrating their ideas.
References


American Association for the Advancement of Science (1989). *Science for all americans: A project 2061 report on literacy goals in science, mathematics, and technology*. Washington, D. C.

American Association for the Advancement of Science (1993). *Benchmarks for science literacy*. Oxford University Press, N.Y.


Appendix A

Starter Sheet for Drawing Tasks
Appendix B

Student Journal Cover (ETG)

My Journal About

Plant Growth

and Nourishment
Appendix C

Tentative Daily Schedule (ETG)

Experimental Treatment Group

Tentative Daily Schedule

Week 1

Monday

Pretests are administered.

Tuesday (10-5-93)

Pretests for absentees.

Wednesday (10-6-93)

Day 1 Set A
Students observe plants and construct graphic models and captions depicting nutrition and growth processes. Predict outcome of plants in light and dark situations on 6th day. Predictions are based upon constructed model. Teacher facilitates comprehensive construction of model without instructing how to construct. Statements such as the following are used: "You show your plant will grow during the next 6 days. I don't see a source of food. Is it necessary during this time?"
Journal entry: "The things that help a plant to live and grow are .... My plant in the light will .... My plant in the dark will .... ."

Thursday (10-7-93)

Day 2 Set B
Based upon current plant model, the students will make predictions about the outcome after the 6th day for planted seeds planted in soil and maintained in light and dark. Teacher's role is similar to the previous day. Journal entry: "The things that help or cause a seed to sprout are .... My seed in the light will .... My seed in the dark will .... ."

Friday (10-8-93)

Day 3 Set C
Students observe plants rooted in Perlite™ irrigated with water and minerals. Based upon this model, they will predict the outcome of these plants after some are left in sunlight for 6 days and some in darkness for 6 days. The teacher's role is equivalent to the previous days. Journal entry: "Plants (need/don't need) soil to grow because .... My plants in Perlite and sunlight will .... My plants in Perlite and darkness will .... ."

Week 2

Tuesday (10-12-93)

Day 4 Set A
Students observe the plants from set A, (10-6-93) that were placed in light and dark environments for 6 days and compare the outcome of the plants to the models representing their earlier predictions. Then, they should make adjustments to their models which represent the actual outcome of the plant and provide reasons for the change. The teacher's role is to facilitate graphic and textual rationales for each of the changes in a student's model. A teacher might say, "You show light helping one plant but not how it helps. Indicate what you think it might do. Also, you show the plant didn't eat in the dark. Can you show what light has to do with eating?" The teacher also points out that all variables except light are kept the same. Light is the experimental variable and likely accounts for the differences if there are any. Journal entry: "My plants (did/did not) perform as I had predicted because .... Plants (need/don't need) light to grow because .... ."

Wednesday (10-13-93)

Day 5 Set B
Students observe the seedlings which sprouted in light and darkness from Set B, (10-7-93) during the last 6 days. They compare the outcome of the plants to their models which represent their earlier predictions. Then, they
should make adjustments to their models which represent the actual outcome of the plant and provide reasons for the change. The teacher’s role is the same as that for Set A (10-12-93). In this case, light is the experimental variable. The seedlings are then placed in a lighted area and one of each set (now called Set B) is restricted from watering. The students will provide graphic and textual models to predict the outcome on 10-26-93 (13 days). Point out that water is the experimental variable now. If other things remain the same (light, temperature, etc.) any changes are probably due to the changes in watering. Journal entry: "Seeds (need/don’t need) light to sprout because .... The plants without water (will/will not) grow because .... Plants get their food from .... The things plants need to make food are ...."

Thursday (10-14-93) Day 6 Set C. The students observe the plants from Set C (10-8-93) that were placed in light and dark environments for a period of 6 days and compare their plants to the models representing their earlier predictions. Then, they should make adjustments to their models which represent the actual outcome of the plant and provide reasons for the change. The teacher’s role is the same as it was for earlier tasks (see 10-12-93). The teacher also points out that light is the only variable changed in this set. Therefore, any differences in the sets is probably due to light changes. The students are also given plants rooted under the following conditions and labeled E: Perlite™ irrigated with distilled water and soil irrigated with distilled water. Also, Perlite™ irrigated with water and dissolved minerals. They are to use their current model of a plant to predict the outcome of each of these plants after 13 days (10-27-93). Journal entry: "My plants (did/did not) perform as predicted because .... Plants (do/do not) need light to grow because ...."

Week 3

Tuesday (10-19-93) Day 7 & Wednesday (10-20-93) Day 8 Sets A2 & C2. The students will examine their plants and models of Sets A2 and C2 grown in sunlight. The experimental variable for these two sets is now root media (soil and Perlite™). They will compare their two models and make adjustments as necessary. The teacher’s role is to facilitate students’ generation of ideas which are depicted in graphics and text. Further, the teacher assures that the students are considering the aspect of comparison by controlled variables. Journal entry: There (is/is not) a difference between the plants grown in soil and Perlite™ irrigated with water and dissolved minerals because ...."

Week 4

Tuesday (10-26-93) Day 9 & Wednesday (10-27-93) Day 10 Set E. The students will compare the 2 plants grown in Perlite™ with dissolved minerals and distilled water. The outcome of each is compared to the plant grown in soil irrigated with distilled water. The teacher’s role is as it has been in previous activities. The teacher facilitates activity which enhances the student’s ability to make informed journal entries and to resolve any contradictions between text and graphics and between models created on different days. Journal entry: "Plants grown in Perlite™ (with/without) minerals are (alike/different) because .... Plants grown in soil without added minerals (did/did not) grow as well as those with added minerals because .... Perlite™ with minerals added is (the same/different) from soil without added minerals because ...."
Thursday (10-28-93) Day 11 Sets A, B, C, and E. The students will compare the models of these sets and attempt to consolidate them into one model representing a plant. The teacher’s role is to facilitate students to consolidate all of their earlier plant models into one without any represented contradictions. Any contradictions such as one plant needing soil to eat and another not needing soil must be resolved or the student must maintain 2 separate models. Journal entry: "My plant models are (alike/different) because ... ."

Week 5

Tuesday (11-2-93) Day 12 The students form into small groups (4-6 per group) and compare their models to other group member models. They are asked to consolidate their models into one model per group which they feel represents a real plant. Each student makes his/her own journal entry as follows: Journal entry: "A plant is ... ."

Wednesday (11-3-93) Day 13 A transparency of the starter picture the students composed their models from is projected onto a screen. A random selection is made for one team to complete the starter picture such that it depicts their model of a plant. Each subsequent group is given a chance to affirm the model or to challenge it. The teacher’s role is to act as mediator and to use the outcome of the actual plants to establish consensus on any arguments. The teacher will also introduce the role of carbon dioxide at this point. Journal entry: "I (agree/disagree) with the model because ... ."

Thursday (11-4-93) Posttests are administered.

Friday (11-5-93) Posttests for absentees.

Week 6

Monday, Tuesday, & Wednesday (11-8, & 9-93) Interviews are conducted with a total of 12 children.

Delayed posttests are administered on 11-19-93.
Appendix D

Community Plant Model
Appendix E

Instrument for Pretest and Two Posttest

Please tell me what YOU think by completing the statements or answering the questions below. I need to know what YOU think! Thanks for your help.

1. Something is considered to be food when

2. Food for plants is

3. Plants get their food from

4. If plants can be fed, how do we feed them?

5. A plant uses its roots to

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6. A plant uses its stems to

7. A plant uses its leaves to

8. A plant uses soil to/for

9. A plant uses carbon dioxide to/for

10. A plant uses sunlight to/for

11. Photosynthesis is
Name ___________________________________________ 
Boy   Girl 
(circle one) 

My date of birth is { } { } { } 
month   day   year 

I feel that what I know about plants is ________________________________
______________________________
______________________________
______________________________
______________________________

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Appendix F

Plant Preference Model for Interview
Vita

Byron Levy Launey, a native of Louisiana, fulfilled his childhood goal of becoming a teacher and an airplane pilot. Although he was able to pursue both professions simultaneously for a short while, reality demanded that only one could remain an active profession. After 11 years of working with elementary, middle school, and junior high school children in parochial and public schools, and almost 10,000 hours of flying, the choice was clear. The real fulfillment and challenge was in contributing to the education of teachers, children, and aspiring aviators. Aviation instruction is still a part of his life even if corporate and air carrier aviation are former professions.

Byron Launey currently lives with his wife, Laura, his small son Marcus, and his mother, Angela, in the family home located in Mamou, LA.