EFFECTS OF INVESTIGATIVE LABORATORY INTEGRATION ON STUDENT CONTENT KNOWLEDGE AND SCIENCE PROCESS SKILL ACHIEVEMENT ACROSS LEARNING STYLES

By

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This document is dedicated to my wife Margaret and my son Timothy.

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TABLE OF CONTENTS

Page

CHAPTER

APPENDIX

LIST OF TABLES

LIST OF FIGURES

Abstract of Dissertation Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Doctor of Philosophy

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The purpose of this study was to determine the effect of investigative laboratory integration on student content knowledge achievement and science process skill achievement across learning styles, gender, and ethnicity. The independent variable in this study was the teaching method used in the agricultural education classes. The treatment groups utilized one of three levels of treatment: the subject matter approach without laboratory experimentation, subject matter approach with prescriptive laboratory experimentation, and subject matter approach with investigative laboratory experimentation. Characteristics that were treated as antecedent variables were student learning style, ethnicity, and gender. Covariates were used to adjust group means in order to compensate for previous knowledge of the subject matter. This study was conducted using a quasi-experimental design referred to as nonequivalent control group design. A purposively selected sample based upon the ability of the teacher to effectively deliver all three teaching approach treatments was selected from the population of students enrolled in an introductory agriscience course in Florida.

Regression analyses were used to develop separate prediction models for content knowledge achievement and science process skill achievement. It was reported that learning style, teaching method, ethnicity, content knowledge pretest scores, and science process skill pretest scores accounted for 33% of the variance in content knowledge gain score. It was also reported that learning style, gender, teaching method, science process skill pretest scores, and content knowledge pretest scores accounted for 36% of the variance in science process skill gain score.

Multivariate analyses of covariance were conducted to determine the influence of the teaching method and learning style. Significant differences in content knowledge and science process skill gain scores were reported. Those students taught using the subject matter approach or the investigative laboratory approach were reported as having higher content knowledge and science process skill gain scores than students taught using the prescriptive laboratory approach.

Participants in this study tended to white males in the ninth grade with a field-dependent learning style. Based on these findings, recommendations for practitioners and researchers were given.

CHAPTER 1
INTRODUCTION

The idea that teaching involves both art and science has become more generally agreed upon by those in the education profession (Berliner, 1987). The practitioner of this somewhat paradoxical skill requires preparation and practice to become a master at this craft. Within the profession of agricultural education, an additional, somewhat contradictory, dialogue is occurring. This discussion is attempting to answer the question, “Is agricultural education vocational or academic?”

The language found in the Smith-Hughes Act supports the contention of the vocational nature of the profession. This act, passed in 1917, defined agricultural education as a vocational subject matter (Hillison, 1996).

Phipps and Osborne (1988) opined that one of the objectives of a comprehensive program of agricultural education is to assist present and prospective workers in agricultural occupations. This adds credence to the vocational side of the debate. However, since this text was written fifteen years ago, has the nature of agricultural education changed?

Phipps and Osborne (1988) further suggested that promoting meaningful and practical applications of the content of other subject matter areas, such as science and mathematics, is also an objective of the comprehensive agricultural education program. This clearly supports the idea of agricultural education as an academic subject. Additional support for this claim is found in the Hatch Act. This act, passed 30 years prior to the Smith-Hughes Act, emphasized the scientific roots of agriculture, and thus aligned its study with that of other academic subjects (Hillison, 1996).

So, is agricultural education vocational or academic? The answer may be that it is both. In its report, the Committee on Agricultural Education in Secondary Schools (National Research Council, 1988) called for the curriculum of agricultural education programs to expand. The emphasis of this expansion was greater inclusion of scientific subject matter into the curriculum. This expansion was not a call to completely abandon agricultural education's vocational past, rather the report called for the "teaching of science through agriculture" (p. 5). Within this new and broadened curriculum, programs were still expected to prepare students for current and future career opportunities in agriculture.

The scientific literacy needs of individuals entering careers in agriculture, like all careers, are increasing in importance. Employees in today's job market need to know how to learn, reason, think creatively, make decisions, and solve problems. Science education and agriscience education can contribute in an essential way to the development of these skills in our students (National Academy of Science, 1996).

An additional reason for the integration of science-based concepts into the agricultural education curriculum involves the recruitment of students into agricultural education programs. Myers, Dyer, and Breja (2003) identified revising the curriculum to include science-based agriculture concepts as one of the most successful recruitment strategies employed by successful secondary agricultural education teachers. By helping to recruit and retain students into agricultural education programs, the mandate of increasing the number of students who receive education in and about agriculture can better be accomplished (National Research Council, 1988).

Statement of the Problem

With the need for the inclusion of science-based concepts into the agricultural education curriculum, new methods for teaching these materials need to be investigated. The science education literature tells us that shifting to an emphasis on active science learning requires a shift away from traditional teaching methods (National Academy of Science, 1996).

One of the more commonly used texts on teaching methods in agricultural education is *Methods of Teaching Agriculture* (Newcomb, McCracken, Warmbrod, & Whittington, 2004). Within this text, the authors describe the major areas which constitute the subject matter to be taught in agricultural education as agricultural production, agricultural supplies and services, agricultural mechanics, agricultural products, ornamental horticulture, agricultural resources, and forestry. The teaching methods espoused in this text focus on how to most effectively teach material in these content areas. However, there is no mention of how effective these techniques are at teaching science-based agriculture lessons.

Since the 1988 call by the National Research Council, there has been a proliferation of agriscience based texts for use in middle and high school agricultural education programs (Buriak & Osborne, 1996; Cooper & Burton, 2002; Herren, 2002; Osborne, 1994). However, little research has been conducted in the field of agricultural education to determine how to best utilize these new materials.

In their book sponsored by the National Research Council, *How People Learn*, Bransford, Brown, and Cocking (2000) surmised that a major goal of teaching is to prepare students to be able to adapt knowledge to various problems and settings. The authors identified several key features that teachers should employ in their lesson planning to best facilitate the learning process in their students. The first of these features is that information should be taught within multiple contexts (Bransford et al., 2000). By teaching information in this manner, students are more readily able to transfer that knowledge into different situations. Agriculture is one such context in which science, mathematics, reading, and technology subject matter can be taught (National Research Council, 1988).

Bransford et al. (2000) submitted that increasing student time on task and student activity in and of itself is not an effective means of increasing student learning. They stated that hands-on activities "*can* be a powerful way to ground emergent knowledge, but they do not alone evoke the underlying conceptual understandings that aid generalization" (p. 22). This idea was addressed in the *National Science Education Standards* (National Academy of Science, 1996). The *Standards* state clearly that "'Hands-on' activities, while essential, are not enough. Students must have 'minds-on' experiences as well" (pg. 2).

To evoke understanding, activities should be integrated into the curriculum to allow students to make their knowledge on the subject explicit. Students must then engage in active mental struggling with how to connect this prior knowledge with the new experiences encountered in integrated activities (Clough, 2002).

A common teaching strategy used by classroom teachers in both science and agricultural education is laboratory activities. However, laboratory activities often fail to engage students in the mental struggle suggested by Clough (2002). Classroom "experiments" bear little resemblance to real experiments (American Association for the Advancement of Science, 1993). The American Association for the Advancement of Science (AAAS) laments its concern over this trend of "cookbook" laboratory activities in its publication *Benchmarks for Science Literacy*.

> [In "cookbook" activities] The question to be investigated is decided by the teacher, not the investigators; what apparatus to use, what data to collect, and how to organize the data are also decided by the teacher (or lab manual); . . . the results are not presented to other investigators for criticism; and, to top it off, the correct answer is known ahead of time. (p. 9)

This group continues to state that teachers and curriculum developers should eliminate the "mechanical, recipe-following aspects" (p. 9) of these laboratory activities.

The elimination of these aspects of classroom laboratory activities does not mean that all classroom experiments must be conducted without teacher guidance and direction. As Clough (2002) noted, teachers are too busy to develop and implement every laboratory experiment used in their classrooms to meet the standards set by the AAAS. However, traditional prescriptive laboratory activities that have been used in the past and are commonly provided by textbook publishers can be modified to allow more student investigation. In addressing this issue, Clark, Clough, and Berg (2000) state,

> In rethinking laboratory activities, too often a false dichotomy is presented to teachers that students must either passively follow a cookbook laboratory procedure or, at the other extreme, investigate a question of their own choosing. These extremes miss the large and fertile middle ground that is typically more pedagogically sound than either end of the continuum. (p. 40)

It is this middle ground described by Clark, Clough, and Berg that investigative laboratory activities attempt to address.

The integration of investigative laboratory activities combines the aspects of traditional laboratory experiment modification espoused by Clark, Clough, and Berg (2000), the mental engagement prescribed by Bransford et al. (2000), and the foundations of experiential learning promoted by Kolb (1984). Kolb stated that students should come into contact with a concrete experience when introduced to new information. This experience provides them with a reference point upon which to reflect as they travel through the educational process.

Additionally, investigative activity integration focuses on student inquiry as a learning method. The *Standards* (1996) state that inquiry is key to student understanding of science.

> Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (p. 23)

The foundations of investigative activity integration are supported by the American Association for the Advancement of Science. The AAAS (1990b) states that students are better able to learn about things that are tangible and directly accessible to their senses. The AAAS continues to suggest that concrete experiences that occur within a context are most effective. This contextual structure can be provided by teaching science concepts in the context of agriculture (National Research Council, 1988).

The *Standards* (1996) do offer a caution, indicating that conducting hands-on activities does not guarantee inquiry. Additionally, hands-on activities are not the only way in which students can engage in inquiry. What is key, however, is that inquiry activities are conducted to answer authentic questions generated from student experience (National Academy of Science, 1996).

A review of research conducted in agricultural education revealed results that are inconclusive, at best, in identifying the most effective teaching methods to be used by teachers for science-based agriculture lessons. Moreover, most research dealing with student content knowledge achievement in agricultural education has relied on descriptive and causal-comparative methods (Edwards, 2003). Slavin (2003) stated that more studies utilizing experimental designs are needed in this area.

Furthermore, a review of research produced few studies that addressed the effect of investigative activity integration on student content knowledge achievement or science process skill development. To address the concerns of Edwards (2003) and Slavin (2003) regarding research of this type, this study was conducted using a quasi-experimental design.

The problem addressed in this research contained two parts:

- limited agriscience content knowledge achievement of some agriscience students,
- little empirical evidence regarding the most effective strategies for teaching agriscience concepts

This study investigated the effect of investigative laboratory integration on content knowledge achievement and science process skill development of students of differing learning styles. This study sought to determine if integrating investigative laboratories in a manner that would encourage students to engage mentally in the activity at a higher level would significantly affect content knowledge achievement and science process skill proficiency level. Findings from this study could provide an important addition to the knowledge base. This information could be utilized by both agricultural education teachers in middle school and high school settings, as well as by teacher educators at colleges and universities, in the preparation of teachers.

Purpose of the Study

The primary purpose of this study was to determine the effect of investigative laboratory integration on student content knowledge achievement and science process skill development across different learning styles. The specific objectives and hypotheses of this research were as follows:

Statement of Objectives

1. Describe the learning styles, ethnicity, and other demographic characteristics of participants in this study.
2. Describe the variance in content knowledge gain score attributed to learning styles, ethnicity, and other demographic characteristics.
3. Describe the variance in science process skill gain score attributed to learning styles, ethnicity, and other demographic characteristics.

Statement of Hypotheses

For the purpose of statistical analysis, the research questions were posed as null hypotheses. All null hypotheses were tested at the .05 level of significance.

- HO_1: There is no difference in the content knowledge gain scores of agricultural education students taught using the subject matter, prescriptive laboratory, or investigative laboratory approaches.
- HO_2: There is no difference in the content knowledge gain scores of agricultural education students of various learning styles.
- HO_3: There is no difference in the content knowledge gain scores of agricultural education students of varying learning styles taught using the subject matter, prescriptive laboratory, or investigative laboratory approach.
- HO_4: There is no difference in the science process skill gain scores of agricultural education students taught using the subject matter, prescriptive laboratory, or investigative laboratory approach.
- HO_5: There is no difference in the science process skill gain scores of agricultural education students of various learning styles.
- HO_6: There is no difference in the science process skill gain scores of agricultural education students of varying learning styles taught using the subject matter, prescriptive laboratory, or investigative laboratory approach.

Definition of Terms

For the purpose of this study, the following terms were defined operationally:

- *Agricultural education*: a term used to represent the profession of teaching students about all areas of agriculture from production to consumption. In most cases this term was used to represent formal instruction in agriculture conducted in a middle school or secondary school settings.
- *Agriscience Foundations*: the first course in most secondary Agriscience and Natural Resources programs in the State of Florida. This course satisfies a requirement of a science with a laboratory component towards graduation.
- *Content Knowledge Achievement*: the number of correct responses on the content knowledge achievement test administered immediately after the treatment.
- *Ethnicity*: this student characteristic was categorized as White, Black, and Hispanic.
- *Inquiry-based science*: an approach used for teaching and learning science that stresses the engagement of students in the process of finding out about natural phenomena, constructing their knowledge of scientific conceptions, and reflecting on the degree to which the learning corresponds to authentic science (Kenyon, 2003).
- *Investigative laboratory exercise*: laboratory exercises in which the students develop the procedures to follow to investigate a scientific question. The classroom teacher provides guidance and advice, but does not inform students of expected outcomes prior to student completion of the exercise.
- *Learning style*: the individual's preferred method of perception and processing. Leaning style refers to the way each person perceives, sorts, absorbs, processes, and retains information (Dunn, 1984; Dyer, 1995). Determined by Group Embedded Figures Test (GEFT) (Witkin, Oltman, Raskin, & Karp, 1971) scores. Classified as field-dependent, field-neutral, or field-independent.
- *Prescriptive laboratory exercise*: laboratory exercises in which the teacher provides clear step-by-step instructions to the students. In addition, the teacher provides information as to the expected outcome of the exercise prior to student completion of the exercise.
- *Retention of content knowledge*: the number of correct responses on the content knowledge retention test administered four weeks after the treatment.
- *Science process skills*: ability to plan, conduct, and interpret results from scientific investigation. Determined by Test of Integrated Process Skills (TIPS) (Dillashaw

& Okey, 1980). Specifically, the skills of observing, comparing, classifying, quantifying, measuring, experimenting, inferring, and predicting are assessed.

- *Subject matter approach*: an expository teaching strategy in which the teacher assumes full responsibility for determining what and how subject matter will be learned as characterized by Flowers (1986). Rosenshine and Stevens (1986) suggest a six step model for this approach that includes a daily review, presentation of new material, guided student practice, feedback, independent student practice, and reviews (evaluation).

Limitations of the Study

The conclusions and implications drawn from this study are subject to the following limitations:

- The data are limited to those obtained from purposively selected Florida agricultural education students. Teachers were purposively selected. Therefore, generalization of the results of this study to other groups will be limited to the degree to which those groups match the population and sample used in this study.
- The results are limited to the extent that they reflect only one unit of instruction common to all agriculture programs included in the sample.

Assumptions of the Study

The following assumptions were made for the purposes of this study:

- The students involved in this study performed to the best of their ability.
- Learning styles and science process skills of students can be accurately identified using written assessments.

Chapter Summary

The primary purpose of this study was to determine the effect of investigative laboratory integration on student content knowledge achievement and science process skill development across different learning styles. This chapter provided a description of the rationale for evaluating the effects of investigative laboratory integration in secondary agricultural education courses.

The significance and justification of the study was also discussed. The findings contained in the literature base are inconclusive as to the best methods in which to teach science-based agricultural education content. The information gained from this study should be of value both to practicing agricultural education teachers and teacher educators. By understanding ways in which to best integrate science into the agricultural education curriculum, the profession can better position itself with other content areas to assist students to succeed not only on state mandated examinations, but in life in general. Additionally, for agricultural education to remain a viable and relevant component of public education, the profession must show how the curriculum addresses the academic standards set by many state departments of education (Shinn, 2002). By integrating science concepts, which address the science standards, agricultural education is better able to secure its place at the educational policy and funding table.

The research objectives were also included in this chapter. The specific objectives and hypotheses of this research were reported as follows:

1. Describe the learning styles, ethnicity, and other demographic characteristics of participants in this study.
2. Describe the variance in content knowledge gain score attributed to learning styles, ethnicity, and other demographic characteristics.
3. Describe the variance in science process skill gain score attributed to learning styles, ethnicity, and other demographic characteristics.

- HO_1: There is no difference in the content knowledge gain scores of agricultural education students taught using the subject matter, prescriptive laboratory, or investigative laboratory approach.
- HO_2: There is no difference in the content knowledge gain scores of agricultural education students of various learning styles.
- HO_3: There is no difference in the content knowledge gain scores of agricultural education students of varying learning styles taught using the subject matter, prescriptive laboratory, or investigative laboratory approach.

- HO_4: There is no difference in the science process skill gain scores of agricultural education students taught using the subject matter, prescriptive laboratory, or investigative laboratory approach.
- HO_5: There is no difference in the science process skill gain scores of agricultural education students of various learning styles.
- HO_6: There is no difference in the science process skill gain scores of agricultural education students of varying learning styles taught using the subject matter, prescriptive laboratory, or investigative laboratory approach.

Chapter 2 will describe the theoretical and conceptual framework of this study. Furthermore, the empirical research contained within the literature base of agriculture education relevant to this study will be described.

CHAPTER 2
REVIEW OF THE LITERATURE

Chapter 1 described the rationale for evaluating the effects of investigative laboratory integration in secondary agricultural education courses. The primary purpose of this study was to determine the effect of investigative laboratory integration on student content knowledge achievement and science process skill development across different learning styles.

This chapter describes the theoretical and conceptual frameworks, and delineates the empirical research relevant to this study. The review of the literature base focused on textbooks, refereed and non-refereed publications in agricultural and science education, and articles appearing in the ERIC Documentation Reproduction Service. Included in this chapter is a review of literature and research pertaining to the following:

- context variables
    - learning style
    - gender
    - ethnicity
- process variables
    - subject matter approach
    - experiential learning
    - inquiry-based approach
- presage variables
- product variables
    - content knowledge achievement
    - science process skills

Theoretical Model of the Teaching and Learning Process

Mitzel (1960) proposed that teaching effectiveness criteria could be classified according to goal-proximity as product criteria, process criteria, or presage criteria. The

Mitzel model (Dunkin & Biddle, 1974) laid the foundation for evaluating teaching effectiveness. This model provided the theoretical framework for the current study (Figure 2-1).

Building upon the teaching effectiveness criteria suggested by Mitzel, the model for the study of classroom teaching identifies variables affecting the teaching-learning process and categorizes them into four groups. These groups are context variables, presage variables, process variables, and product variables.

Context variables, as defined by Dunkin and Biddle (1974), are the conditions to which the teacher must adjust. These are characteristics of the environment about which little can be done. Contained within the category of context variables are four sub-categories of pupil formative experiences, pupil properties, school and community context, and classroom context. Examples of the first sub-category, pupil formative experiences, could be socioeconomic status, age, and gender. Pupil properties could include ability, knowledge, and attitudes. The sub-categories of school and community context and classroom context include the size, ethnic composition, and equipment of each of the respective settings.

Presage variables are those characteristics of teachers that may be examined for their effects on the teaching and learning process. Mitzel (1960) called these "pseudo criteria." He continued by saying that these were criteria that "are from a logical standpoint completely removed from the goals of education" (p. 1484). There are three

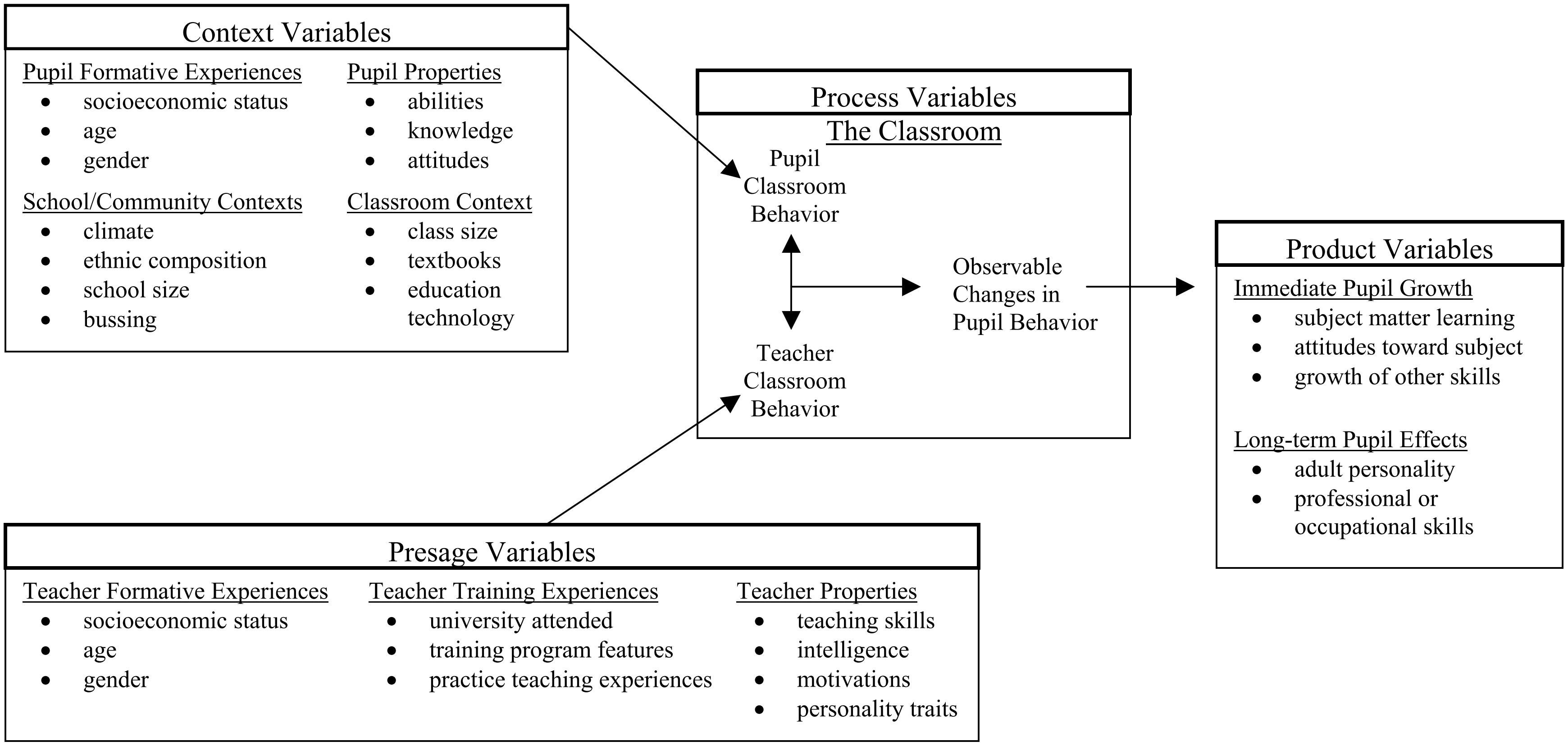

Figure 2-1. Conceptual Model for the Study of Classroom Teaching (Dunkin & Biddle, 1974)

sub-categories of presage variables. They are teacher formative experiences, teacher training experiences, and teacher properties. Teacher formative experiences are the same characteristics as those listed under the pupil formative experiences identified in the context variable. Examples are the teacher's socioeconomic status, age, and gender. Experiences such as the college or university attended by the teacher, courses taken, experiences during practice teaching, and in-service and postgraduate education comprise examples of items that could be found in the teacher training experiences sub-category. Items within this sub-category are the most often studied variables (Dunkin & Biddle, 1974). The final sub-category of presage variable is teacher properties. These are measurable personality characteristics. Examples of items included in this sub-category are teaching skills, intelligence, and motivation.

Process variables include the actual activities of classroom teaching. This variable consists of the classroom behavior of both the teacher and the pupil. The final variable identified in this model is product variables. These are the outcomes of teaching. These are changes that come about in pupils as a result of their involvement in classroom activities with teachers and other pupils. Product variables represent a change in student behavior. Examples of product variables include a change in learning, attitudes, skill development, or adult personality development (Dyer, 1995). These outcomes can be grouped into two categories. The first is immediate pupil growth. This involves the areas of subject-matter learning, attitudes toward the subject, and growth of other skills. The second category is long-term pupil effects. Examples in this area are professional or occupational skills (Dunkin & Biddle, 1974).

Flowers (1986) stated that researchers must address all of these variables in any study involving classroom teaching. He stated that while the researcher may select and examine specific product variables of interest, the other variables must be addressed by the researcher and controlled by either research design or statistical methods.

Product Variables

The product variables of interest in this study are student content knowledge achievement and science process skill development. Referring to Mitzel's model, student content knowledge achievement and science process skill development are measures of immediate pupil growth. Whereas retention of content knowledge would be an example included in the long term pupil effects category of product variables (Dunkin & Biddle, 1974). All of these variables have been observed in previous studies in which contrasting teaching methods were examined (Dyer, 1995; Flowers, 1986). Although these variables are clearly supported by Mitzel's model, and have been researched in a limited number of studies, the majority of studies in the area of agriscience have only examined teacher attitudes and perceptions (Balschweid & Thompson, 1999; Connors & Elliot, 1994; Dyer & Osborne, 1999b; Layfield, Minor, & Waldvogel, 2001; Newman & Johnson, 1993; Peasley & Henderson, 1992; Thompson, 1998; Thompson & Balschweid, 1999; Welton, Harbstreit, & Borchers, 1994).

Student Content Knowledge Achievement

Boone and Newcomb (1990) investigated and compared the effects of problem solving and subject matter teaching approaches on student content knowledge achievement. This quasi-experimental design included 121 freshmen students enrolled in agriculture courses in seven Ohio high schools. Teachers of these classes were purposively selected for their ability to use the problem solving approach. The researchers reported no significant difference in student content knowledge achievement or retention between the students taught using the various teaching approaches.

Dyer and Osborne (1996a) also compared the relative effectiveness of the problem solving approach and the subject matter approach. This study involved six purposively selected teachers who were determined capable of demonstrating both teaching approaches. Within this group of teachers, treatments were randomly assigned to intact classes. The sample included 16 classes with 258 students. The researchers reported that for field-neutral learners, the problem solving approach was found to be more effective in increasing student content knowledge achievement than the subject matter approach. However, no significant difference in content knowledge achievement was reported for field-dependent or field-independent learners exposed to the two teaching approaches.

In a study of student performance through the use of active learning, it was reported that such strategies resulted in improved student attitude toward the subject matter (Blakey, Larvenz, McKee, & Thomas, 2000). However, no change was reported in student content knowledge achievement, as measured by test score. This study was conducted with a sample of fourteen general music classes in western Illinois. Contained within this sample were six 7th grade classes and eight 8th grade classes. The active learning methods and strategies of graphic organizers, cooperative learning, role playing, and think-pair-share were used as the active learning treatment in this study.

In a study includeing seven introductory agriscience classes enrolling primarily ninth grade students (*n* = 132) from five different school districts, Johnson, Wardlow, and Franklin (1998) reported no significant differences in either immediate or delayed cognitive scores between the use of worksheets or hands-on activities. The study further reported no significant interaction between the factors of method or gender. However, significant differences were reported on both immediate and delayed cognitive score based on gender. The researchers reported that females tended to score higher than males on the posttest. This study utilized a randomized post-test-only experiential design with a counter-balanced internal replication.

Connors and Elliot (1995) reported no significant difference in content knowledge achievement, based on a standardized science test, between students who had and had not enrolled in agriscience and natural resources courses. This study found that overall grade point average and the number of science credits completed explained the largest portion of the variance in science achievement score with correlation coefficients of .57 and .49 respectfully. Four high schools which offered agriscience and natural resource classes in Michigan were randomly selected to participate in this study. The sample included 156 senior high school students.

Roegge and Russell (1990) investigated the effect of incorporating biological principles into a unit of instruction in an agriculture course. The study consisted of 104 students in nine schools. A pretest-posttest control group design was used. A significant difference was reported in both overall content knowledge achievement and applied biology achievement, with students in the integrated approach group scoring higher.

Chiasson and Burnett (2001) investigated the effect of agriscience courses on science content knowledge achievement of high school students in Louisiana. This was a census study that included all 11th grade students enrolled in public schools in the state. The researchers reported that agriscience students tended to earn higher scores than non-agriscience students on the science portion of the Louisiana exit examination. The researchers continued by reporting that agriscience students scored as high or higher on four of the five science domain sub-scales. Also, agriscience students were more likely to pass the examination than non-agriculture students.

Science Process Skill

Dillashaw and Okey (1980) developed and tested an instrument to assess the science process skills associated with planning, conducting, and interpreting results from investigations. Collectively these are often referred to as the integrated science processes. Specifically these include skills such as formulating hypotheses, operationally defining, controlling, and manipulating variables, planning investigations, and interpreting data (Livermore, 1964). The instrument was first field tested with samples of approximately 100 students each from grades 7, 9, and 11 in two schools. Revisions were made and the instrument was field tested with a sample of over 700 students from the same grade levels as the first test. This instrument was designed to develop a measure of integrated process skill achievement referenced to a specific set of objectives, and was found to be a valid and reliable measure of science process skill achievement for students in the 7th to 12th grade (Dillashaw & Okey, 1980).

Germann (1989) investigated the effect of the directed-inquiry approach on science process skills and scientific problem solving. The sample for this study included four sections of 9th and 10th grade general biology. Students were grouped by academic ability, with the experimental group consisting of average ability students and the comparison group consisting of above-average ability students. The researcher reported that the use of a directed-inquiry approach had no significant effect on the learning of science process skills or on cognitive development.

Burchfield and Gifford (1995) investigated the development of science process skills of community college students by using computer-assisted instruction. The 92 participants in this study were enrolled in General Biology I for Science Majors at a small, rural community college in the southeastern United States. The study found no significant difference between the mean gain in science process skill proficiency between students instructed with the traditional treatment or those receiving computer-assisted instruction. Neither, student academic aptitude, as measured by scores on the Enhanced American College Testing Assessment, nor gender were found to be factors influencing science process skill development for either treatment.

Mabie and Baker (1996) conducted a study to explore the impact of two types of agriculturally-oriented experiential instructional strategies on science process skills. In this study, three classrooms in Los Angeles consisting of fifth and sixth grade students were observed. A total of 147 students participated in this study. The findings of this study indicated that participation in agriculturally-oriented experiential activities positively impacts the development of science process skills. Participation in experiential activities assisted students in their ability to observe, communicate, compare, relate, order and infer.

Downing, Filer, and Chamberlain (1997) examined if there was a relationship between preservice elementary teachers' competency in science process skills and attitudes toward the field of science. This study included a sample of 46 preservice elementary teachers enrolled in a mathematics and science methods course just prior to student teaching. This study found a moderately positive correlation ($r = .39$) between the preservice teachers' competency levels of science process skill and attitudes toward science.

Osborne (2000) examined the effects of level of openness in agriscience experiments on student achievement and understanding of science process skills. This quasi-experimental study used a nonequivalent control group design. The sample included 150 students from 14 schools. Nearly all students in the sample were 15 or 16 years of age. This study found that the students who participated in the prescriptive laboratories developed higher levels of science process skills and achievement than those students conducting investigative laboratory exercises. However, it was also discovered that in general all the students in the agricultural education courses had very low science process skill scores as measured by the Test of Integrated Process Skills. Osborne recommended that a follow-up study be completed to investigate the effects of learning style on science achievement and process skill proficiency.

Process Variables

The process variables examined in this study were the teaching methods used in the treatment conditions. This study involved three treatment groups utilizing various teaching methods in varying capacities. Treatments differed on the approach to teaching agriscience laboratory exercises. The teaching methods that served as the foundation for these methods were the subject matter approach, experiential learning, and inquiry-based instruction.

Subject Matter Approach

The subject matter approach to teaching is a commonly used teaching method in agricultural education (Flowers, 1986). This method is also commonly used as the "control" treatment in studies investigating the effects of another teaching method, most often, the problem solving approach (Boone, 1988; Dyer, 1995; Flowers, 1986). The subject matter approach is a teacher-centered approach. In utilizing this approach, the teacher selects the content to be studied, explains the importance or relevance of the content, and selects the learning activities to be used to present the information. Typically the content to be delivered is organized around specific, often behaviorist-learning objectives (Mager, 1997).

Flowers (1986) compared the effectiveness of the problem solving approach to the subject matter approach. His study consisted of 126 agriculture students from eight high schools enrolled in an introductory level agriculture course. In this study each teacher taught two courses, one using the problem solving approach and the other using the subject matter approach. Flowers reported no significant difference in student content knowledge achievement, cognitive achievement, retention, attitude, or time required to complete instruction.

Boone (1988) also investigated the effects of teaching approach on student content knowledge achievement, retention of content knowledge, instructional time, and student attitude toward instruction. Similar to Flowers (1986), the teaching approaches tested in this study were subject matter approach and problem solving approach. This study utilized a quasi-experimental counterbalance design as described by Campbell and Stanley (1963). Purposively selected teachers taught two instructional units. One unit was taught using the problem solving approach and the second taught using the subject matter approach. The accessible population for this study was 121 freshman students enrolled in production agriculture classes in Ohio. It was reported that student content knowledge achievement varied according to timing of the unit and instructional approach.

Students taught first with the problem solving approach and then the subject matter approach had higher content knowledge achievement scores and higher scores on attitude toward instruction. It was further reported that both approaches required the same amount of classroom time to complete. Boone also reported that teachers in the study did not fully incorporate the problem solving approach as prescribed by the researcher. Based on this, the researcher recommended that future studies investigating the problem solving approach begin with an inservice series to instruct teachers on the problem solving approach.

Dyer (1995) conducted a study following similar procedures to that of Boone (1988) and Flowers (1986) with the addition of examining the effect of student learning style and instructing teachers in the proper use of both the problem solving and subject matter approaches. The sample of this quasi-experimental study consisted of 133 students from 12 classes. It was reported that the problem solving approach produced significantly higher scores in student problem solving ability across all learning styles. A significant increase in content knowledge achievement score was reported for field-neutral learners. No significant differences were detected across learning styles on retention scores. The study also reported that the majority of ninth grade students were field-dependent in their learning style. Furthermore, problem solving ability was reported to increase by grade level and was highest for field-independent learners.

By synthesizing research that had been conducted in education and other related areas, Rosenshine (Rosenshine & Stevens, 1986; Rosenshine, 1987) presented a model of effective instruction (Figure 2-2) when utilizing the subject matter approach. There are six major steps in this model: (1) review previous day’s work, (2) present new content,

(3) guided student practice, (4) feedback and correctives, (5) independent student practice, and (6) weekly and monthly reviews.

In the first step of reviewing the previous day's work, Rosenshine and Stevens (1986) presented two purposes for completing this step: it provides additional practice and overlearning for previously learned material, and it allows the teacher to provide corrections and reteach areas in which students are having difficulty. This step may be accomplished through questioning techniques, student peer reviews, or a short quiz.

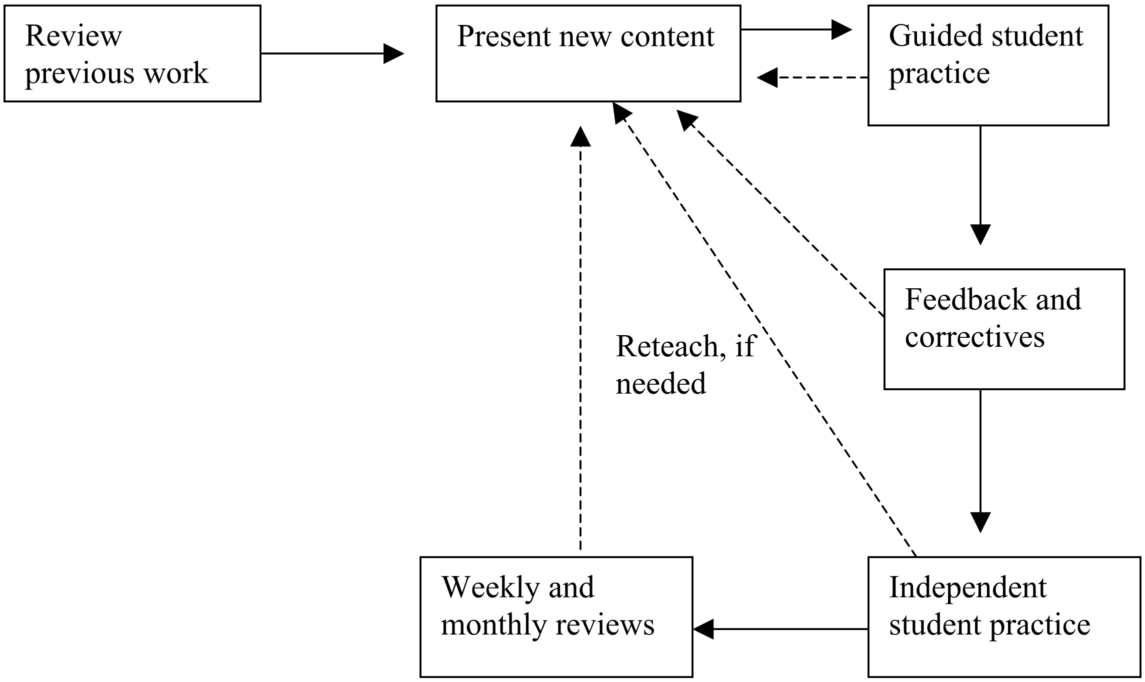

Figure 2-2. Rosenshine's Model of Effective Instruction (Rosenshine, 1987)

The steps of presenting new material and student guided practice are very closely aligned according to Rosenshine's (1987) model. After new material is presented and demonstrated by the teacher, guided student practice should follow (Rosenshine & Stevens, 1986). The purpose of guided practice is to check for student understanding of the concept. The teacher should reteach the material if it is determined that a substantial number of students have failed to learn the material.

Following student guided practice, students should be given the opportunity to practice using the new knowledge or skill on their own. The goal is to allow students to integrate the information or skills with previous knowledge and to become automatic in their use of the information (Rosenshine & Stevens, 1986).

Weekly and monthly reviews were also found to improve the learning of new material. These reviews provide a teacher with another point in which to check the students' understanding of the material (Rosenshine & Stevens, 1986).

Experiential Learning

The experiential learning theory proposed by Kolb (1984) was built upon the foundations laid by Lewin, Dewey, and Piaget. Kolb suggested that experiential learning provides a foundation for an approach to education and learning whose theoretical basis is located with social psychology, philosophy, and cognitive psychology.

Dewey (1938) opined that "there is an intimate and necessary relation between the processes of actual experience and education" (p. 19, 20). The idea that learning must be accompanied by some real-world experience has been built upon by several researchers. Keeton and Tate (1978) encouraged educational strategies that allowed the learner to have direct interaction with the phenomenon being studies. Merely thinking about the object or idea to be learned was not sufficient. Argyris and Schon (1974; 1978) suggested that learning through experience is essential for individual and organizational effectiveness. The importance of this type of learning experience was described by Chickering (1977) in saying that experiential learning contributes to more complex development intellectually. Learning constructed in this manner assists individuals cope with shifting developmental tasks that are brought on by rapid social change.

Experiential learning theory offers a fundamentally different understanding of how individuals learn than do the behavioral theories. Thus, this different way of learning requires a new approach to teaching (Kolb, 1984). Whereas behaviorist learning theories approach ideas as fixed elements that always remain the same, Kolb's theory states that ideas are formed and re-formed through experience. In support of Kolb, Freire (1974) described the transmission of fixed content supported in the behaviorist idea of learning as the "banking" concept of education. He continued his criticism by suggesting that this "banking" of information allows the individual to extend this knowledge only as far as receiving, filing, and storing.

Kolb (1984) defines learning as the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping experience and transforming it. The cornerstones of Kolb's model are the four adaptive learning modes (Figure 2-3). The first of these is concrete experience. In this mode, students involve themselves fully, openly, and without bias in new experiences. The second mode is reflective observation. In this mode the student reflects on and observes their experiences from many perspectives. Next, students enter the abstract conceptualization mode. In abstract conceptualization, learners create concepts that integrate their observations into logically sound theories. The fourth mode is active experimentation. Students apply the theories developed in the abstract conceptualization mode to make decisions and solve problems.

In the Kolb model, knowledge is a result of a combination of grasping experience and transforming that experience. This model suggests four different elementary forms of knowledge. Divergent knowledge is a result of experience grasped through

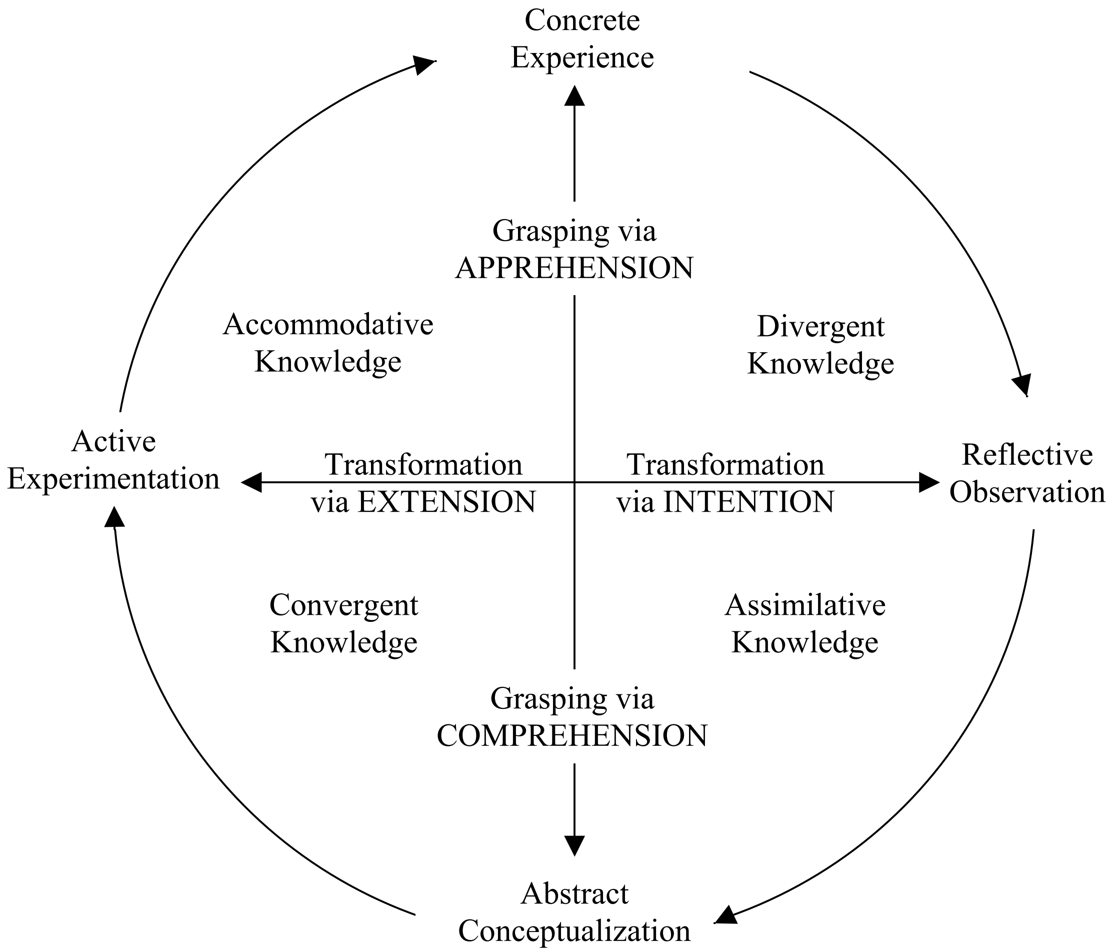

Figure 2-3. Kolb's Model of Experiential Learning (Kolb, 1984)

apprehension and transformed through intention (Kolb, 1984). The idea of grasping through apprehension corresponds closely with James' (1890) views of knowledge of acquaintance. Grasping through apprehension describes the knowledge of something or a familiarity with the object. The transformation via intention can be associated with Piaget's idea of intellectual operations, meaning that these transformations are internalized. Assimilative knowledge is grasped through comprehension and transformed through intention (Kolb, 1984). Comprehension can be likened to James' (1890) knowledge-about. Convergent knowledge is developed when experience is grasped through comprehension and transformed through extension. The final form of knowledge is accommodative knowledge. It is developed when experience is grasped by apprehension and transformed by extension (Kolb, 1984). Kolb's continuous cycle model calls for learners to be engaged in all four modes of learning, developing all four types of knowledge.

Powell and Wells (2002) compared the effectiveness of three experiential teaching approaches on student science learning. Twelve fifth-grade classes with 211 students in a Colorado school district were assigned to each of three treatment groups. The researchers reported no significant differences between treatment groups suggesting that lessons adapted to meet Kolb's four stages of learning may not necessarily lead to more effective means of knowledge acquisition.

Hakeem (2001) investigated the effect of experiential learning in a business statistics course. Participants in this study were undergraduate students at a regional 4-year university. A total of 213 students were randomly divided into two groups, one would be involved in experiential activities as part of the course the other would not. Hakeem reported that students who had participated in the experiential learning project had significantly higher scores on the content knowledge achievement test that measured more complicated concepts. No significant difference was found between the groups, as measured by content knowledge achievement tests, on traditional statistics techniques requiring formulas and hand computations.

Schlager, Lengfelder, and Groves (1999) examined the use of experiential education as an instructional methodology for travel and tourism classes. The sample for this study included students enrolled in two graduate travel and tourism courses at a 4-year university in Ohio. The researchers reported that students in the sections that used experiential methods had a greater preference for less structured instructional methods and that these methods lead to higher motivation.

Wulff-Risner and Stewart (1997) compared two experiential teaching methods on learning outcomes of 8-18 year old students. This quasi-experimental study included a sample of 98 students who participated in a workshop on horse judging in Missouri. The researchers reported that students taught in the classroom videos and pictures scored significantly higher on achievement tests for both conformation judging skills and performance judging skills than did students taught with live animals.

Inquiry-based Instruction

As the agricultural education profession works to expand its research base regarding teaching methods to deliver scientific concepts effectively, the work completed in this area by our colleagues in science education should be examined. The science education literature states that shifting to an emphasis of active science learning requires a shift away from traditional teaching methods (National Academy of Science, 1996). The report by the American Association for the Advancement of Science (AAAS) titled *Science for All Americans* (1990b) emphasized that the teaching of scientific concepts should be consistent with the nature of scientific inquiry. Furthermore, the *National Science Education Standards* (National Academy of Science, 1996) state that inquiry is central to learning science.

The process skill approach (Chiappetta & Koballa, 2002) is one teaching method discussed in the science education literature that could be employed by agriculture teachers in the effort to teach science as inquiry. Although these process skills are not listed specifically in the *National Science Education Standards* (National Academy of

Science, 1996), they have been integrated into the broader abilities of scientific inquiry (National Research Council, 2000).

The process skill approach focuses on teaching broadly transferable abilities that are appropriate to many science disciplines and are reflective of the behavior of scientists (Padilla, 1990). Chiappetta (1997) states, “the acquisition and frequent use of these skills can better equip students to solve problems, learn on their own, and appreciate science” (p. 24). The science process skills can be classified as either basic or integrated (see Table 2-1). The basic science process skills are designed to provide a foundation for learning the more complex integrated science process skills (Padilla, 1990). Examples of integrated science process skills include skills such as formulating hypotheses, operationally defining, controlling, and manipulating variables, planning investigations, and interpreting data (Livermore, 1964).

It is important that inquiry-based instruction be conceptualized as teaching both the content (what) and the process (how) of science (Chiappetta & Adams, 2004). *Inquiry and the National Science Education Standards* (National Research Council, 2000) outlines three facets of inquiry-based instruction for students to aid in their understanding to these two components of science. In this report, the authors opined that students should (1) learn the principles and concepts of science; (2) obtain reasoning and procedural skills of scientists by conducting investigations, critical thinking, and problem solving; and (3) understand how scientific knowledge is created, processed, and represented by scientists at work. One way to address these components is through the use of investigative laboratory exercises.

Table 2-1 Basic and Integrated Science Process Skills

Process Skill	Definition
Basic Skills	
Observing	Noting the properties of objects and situations using the five senses
Classifying	Relating objects and events according to their properties or attributes
Space/time relations	Visualizing and manipulating objects and events, dealing with shapes, time, distance, and speed
Using numbers	Using quantitative relationships
Measuring	Expressing the amount of an object or substance in quantitative terms
Inferring	Giving an explanation for a particular object or event
Predicting	Forecasting a future occurrence based on past observation or the extension of data
Integrated Skills	
Defining operationally	Developing statements that present concrete descriptions of an object or event by telling one what to do or observe
Formulating models	Constructing images, objects, or mathematical formulas to explain ideas
Controlling variables	Manipulating and controlling properties that relate to situations or events for the purpose of determining causation
Interpreting data	Arriving at explanations, inferences, or hypotheses from data that have been graphed or placed in a table
Hypothesizing	Stating a tentative generalization of observations or inferences that may be used to explain a relatively larger number of events but that is subject to immediate or eventual testing by one or more experiments
Experimenting	Testing a hypothesis through the manipulation and control of independent variables and noting the effects on a dependent variable; interpreting and presenting results in the form of a report that others can follow to replicate the experiment

Note: Adapted from Padilla (1990)

An investigative laboratory exercise differs from the traditional “cookbook” laboratory activities in that investigative exercises allow the student to design an experiment that addresses a problem of their choosing. In traditional laboratory exercises, students are given prescribed directions to carry out activity which is designed to demonstrate the phenomena or reinforce concepts given in a lecture (Sundberg &

Moncada, 1994). Thornton (1972) provided a list of characteristics common to all investigative laboratories.

- Students are aware that the purpose is to engage in investigation
- An initial series of activities prepares students to investigate
- In consultation with the instructor, students formulate problems and procedures
- Adequate time is given to repeat and/or modify experiments
- Students prepare written and/or oral reports

Sundberg & Moncada (1994) provide three variations that can be made to the listing provided by Thornton. The first involves beginning a unit of instruction with a prescriptive or "cookbook" laboratory activity. Upon the completion of this exercise, students used data gathered as a starting point for further investigation. A second variation employs inquiry laboratories. Inquiry laboratories are more directed in nature than investigative laboratories as described by Thornton. In inquiry laboratories, the teacher leads students in discovery of a certain concept or relationship by posing a series of "What happens if…?" questions. The final alternative suggested by Sundberg & Moncada is the open-inductive laboratory. This form of investigative laboratory does not include a series of activities which are designed to prepare the students to investigate. Students are given only minimal direction as to the design and procedures for their investigation.

Laboratory Instruction

Heins Rothenberger and Stewart (1995) investigated the effectiveness of instruction in horticulture using and not using a greenhouse experience with the traditional classroom lecture/discussion technique. This study used a cluster sampling technique and included 168 high school agricultural education students. It was reported that students who received a greenhouse laboratory experience scored significantly higher on the knowledge test. No significant difference was reported between the post-experiment attitude toward poinsettia production group scores for the two groups.

Johnson, Wardlow, and Franklin (1997) utilized a posttest-only control group experimental design with a counter-balanced replication to determine the effects on cognitive achievement and attitude toward the subject matter of a hands-on activity versus a worksheet in teaching physical science principles. A purposively selected sample of 132 students from seven agricultural education classes in Arkansas constituted the sample for this study. The researchers reported no significant difference in the content knowledge achievement level of students taught with hands-on activity versus those taught with worksheets. However, a significant difference was reported between groups on attitude toward instruction. Students taught with the hands-on instruction method reported a more positive attitude.

Using the same sample as the above study, Johnson, Wardlow, and Franklin (1998) reported that both hands-on and worksheet reinforcement methods were equally effective in supporting learning and retention of subject matter. However, differences on both the immediate and delayed posttests were noted for the main effect of gender. Female students scored significantly higher than did male students.

Context Variables

The context variables examined in this study are student learning style, science process skill, socioeconomic status, gender, and ethnicity. The researcher is aware that there is a multitude of characteristics within the environment to which the teacher must adjust. These variables were selected to be included in the study after an extensive literature review identified these as being some of the more influential characteristics that affect the product variables of interest.

Learning Style

Although a multitude of definitions exist for the term “learning style,” most definitions include at least three of the following underlying concepts:

- Students learn via different ways and means
- Learning styles are personal to the learner
- The way in which a person perceives and processes information (Dunn & Dunn, 1979; Gregorc, 1979; Witkin, Oltman, Raskin, & Karp, 1971)

One of the first to categorize learners based on cognitive style was Jung. His categories were determined based on a person’s relation to the world (introversion/extroversion), decision making (perception/judgment), perceiving (sensing/intuition), and judging (thinking/feeling) (Kolb, 1984). Another pioneering researcher who studied the cognitive-development process in great detail was Piaget. Piaget examined children’s ability to display abstract reasoning in a concrete environment (Kolb, 1984).

One of the criticisms of learning style research is its lack of focus and direction (Dyer, 1995). The literature contains numerous studies on learning styles, yet the lack of consistency in the way in which learning style is measured and the terminology used to describe them has lead to a lack of utilization of this information in the classroom.

Learning Styles Instrumentation

Numerous forms of instrumentation can and have been used to identify individual learning style. For the purposes of this study, only instruments which have been used extensively in the agricultural education literature will be discussed. The three most commonly utilized learning style instruments in agricultural education are:

- Group Embedded Figures Test (GEFT) (Witkin et al., 1971)
- Myers-Briggs Type Indicator (MBTI) (Briggs & Myers, 1977)
- Learning Styles Inventory (LSI) (Kolb, 1984)

Group Embedded Figures Test (GEFT)

One of the simplest and most extensively examined instruments is the Group Embedded Figures Test (GEFT) (Witkin, Moore, Goodenough, & Cox, 1977; Witkin et al., 1971). This learning style instrument divides students into one of two categories: field-independent or field-dependent.

Field-independent learners are more analytical in the way they perceive the world. These learners are able to provide structure and organize information on their own. This ability often leads to field-independent students requiring less teacher guidance in developing strategies to solve problems (Ronning, McCurdy, & Ballinger, 1984). It was reported by Witkin, Oltman, Raskin, and Karp (1971) that at approximately age 24 individuals begin a process of becoming more field-dependent. In addition to being age-related, Witkin et al. reported that males are more likely to be field-independent than females. However, in agricultural education several studies have shown that the majority of females in this profession tend to be field-independent (Cano & Garton, 1994b; Garton, Spain, Lamberson, & Spiers, 1999; Raven, Cano, Garton, & Shelhamer, 1993; Rudd, Baker, & Hoover, 2000; Rudd, Baker, & Hoover, 1998; Whittington & Raven, 1995). In contrast, there have also been several studies to support the gender relationship stated by Witkin et al. (Dyer & Osborne, 1996a, 1996b; Moore & Dyer, 2002; Torres & Cano, 1994).

Individuals classified as field-dependent by the GEFT are normally more social in their nature. They have a global perception of the world which often leads to these individuals finding it more difficult to solve problems (Ronning et al., 1984). This is often a cause of field-dependent learners needing to have structure and organization provided for them by an external source. This could lead to students of this learning style requiring a more student-centered teaching approach and more direction on how to structure and solve agriscience problems.

Myers-Briggs Type Indicator

A second instrument often used in agricultural education is the Myers-Briggs Type Indicator (MBTI). The MBTI measures an individual's learning style as a function of their personality (Briggs & Myers, 1977). This instrument assesses a person's personality by identifying the preferences of a person in gathering information and making judgments. The four preferences are: Extroversion or Introversion (E or I), Sensing perception or Intuition perception (S or N), Thinking judgment or Feeling judgment (T or F), and Judgment or Perception (J or P). The preference of Sensing (S) and Intuition (N) addresses learning styles. The MBTI provides information about the ways learners prefer to perceive meaning (sensing vs. intuition), to express values and commitment (thinking vs. feeling), and to interact with the world (extroversion vs. introversion) (Rollins, 1988, 1990). Students with a Sensing (S) learning style need to move step-by step through new experiences with their senses as fully engaged as possible. This type of learner works best with established routines. They work steadily and patiently and are interested in facts and details. Students with an Intuition (N) learning style like global schemes with broad issues presented first. These students are likely to follow their inspirations and do not like routines (Briggs & Myers, 1977).

Learning Styles Inventory (LSI)

Kolb (1984) developed an instrument called the Learning Styles Inventory (LSI) based upon experiential learning theory. He describes four modes of learning. They are:

Concrete Experience (feeling), Reflective Observation (watching), Abstract Conceptualization (thinking), and Active Experimentation (doing).

Kolb (1984) states that an orientation toward concrete experience focuses on being involved in experiences and dealing with immediate human situations in a personal way. This type of learner uses an intuitive approach to solving problems. A learner oriented toward reflective observation focuses on understanding the meaning of ideas and situations. They emphasize understanding rather than practical application. This type of learner is good at looking at things from different perspectives and appreciating different points of view.

Individuals with an orientation toward abstract conceptualization focus on using logic, ideas, and concepts. This learning style emphasizes thinking as opposed to feeling. This learner enjoys developing and following systematic plans. Learners oriented toward active experimentation focus on actively influencing people and changing situations. This learner emphasizes doing as opposed to observing. This type of learner is good at getting things done and enjoys accomplishment (Kolb, 1984).

Research on Learning Styles

Studies Involving High School Students

Although there has been a significant amount of research regarding the effects of learning styles on achievement of post-secondary students in agricultural education, there has been relatively few dealing with secondary agricultural education students. The following is a discussion of the findings of those studies.

Rollins (1990) identified the learning styles of 668 students in 18 high schools in Iowa using the Myers-Briggs Type Indicator (MBTI). The study found that the majority of students preferred the Sensing learning style. It was reported that individuals of this learning style prefer experiential and activity-oriented instruction. This supported the position of Briggs and Myers (1977) on this learning style. However, contrary to Briggs and Myers, this study found that those students with an Intuitive learning style also preferred learning in the same manner as those with the Sensing learning style. It was also reported that these findings were consistent for both males and females.

Rollins and Scanlon (1991) examined the learning styles of 224 agricultural education students grades 9-12 in Pennsylvania. The researchers use the Learning Style Profile (LSP) developed by the National Association of Secondary School Principals to determine student learning style. The reported learning styles of the agricultural education students in this study were compared to a national sample of 5000 students of similar ages (Keefe & Monk, 1986). Rollins and Scanlon reported that their sample of students preferred more hands-on activities and small groups sizes than the national norm. In addition, the agricultural education students studied reported substantially less-developed skills in cognitive areas of analytical, spatial, discriminating, and sequential skills than the national norm.

Dyer and Osborne (1996a) determined the learning styles of 258 students in 16 agricultural education classes in Illinois. This study utilized the GEFT to identify student learning style. In addition to the categories of field-dependent and field-independent identified by Witkin et al. (1971), Dyer (1995) identified a third category, field-neutral. This study found that students classified as field-neutral in their learning style by the GEFT instrument had higher achievement scores when taught using the problem solving approach instead of the subject matter approach to teaching.

Using the same sample as the previous study, Dyer and Osborne (1999a) compared the retentive effectiveness of the problem solving approach to the subject matter approach. The problem solving approach was reported to be neither more nor less effective than the subject matter approach in producing higher short-term or long-term retention scores. No significant difference was found based on learning style on either short-term or long-term retention scores with either teaching method.

Vicenti-Henio and Torres (1998) assessed the learning style of American Indian students using the GEFT. The sample included all Navajo students enrolled in the agricultural education program in a public high school located on a Navajo reservation which extends across the New Mexico and Arizona state line (n = 78). The researchers reported that the students tended to be field-independent (71%). Males tended to be field-independent as well (76%). However, females were evenly split between field-dependent (50%) and field-independent (50%).

Garton, Spain, Lamberson, and Spiers (1999) described the relationships between students' learning style, instructor's teaching performance, and student achievement in an introductory animal science course. Using the GEFT, student learning styles were reported as 56% field-independent, 22% field-neutral, and 22% field-dependent. Student learning style was reported to have little to no influence on student achievement in the course or their perceptions of the instructors' teaching performance.

Studies Involving Post-Secondary Students

Although a limited number of studies in agricultural education have measured the learning style of secondary students, the learning styles of post-secondary agricultural education students have been investigated in greater frequency. Raven, Cano, Garton, and Shelhamer (1993) described the learning styles of preservice agriculture education teachers at Montana State University (*n* = 18) and The Ohio State University (*n* = 25) using the Group Embedded Figures Test. They reported that the Montana State University students tended to be more field-independent and preferred a more student-centered approach to teaching than did their Ohio State counterparts. Additionally, there was no gender difference found in learning style preference. Both males and females tended to be field-independent.

Cano and Garton (1994a) identified the learning style of preservice agriculture teachers with the Myers Briggs Type Indicator. The sample of this study included students enrolled in a methods of teaching course during the academic years of 1990, 1991, and 1992. The sample included 29 females and 53 males. It was reported that the highest percentage (23.2%) was ESTJ in their personality type. Cano and Garton stated that individuals of this type tend to be practical, realistic, matter-of-fact, and like to organize and run activities. The second most common profile was ISTJ (18.3%). This type of individual is serious, quiet, and logical. The third most common profile was ESFJ (13.4%). Individuals of this personality type are generally warm-hearted, talkative, and work best with encouragement and praise. These individuals main interest is in doing things that directly and visibly affect people's lives.

Using the same sample as the previous study, Cano and Garton (1994b) described the learning styles of the preservice agriculture teachers using the Group Embedded Figures Test. It was reported that the majority (58.5%) of the preservice teachers were field-independent in their learning style. This finding was consistent with both males (60.4%) and females (55.2%) reporting a field-independent learning style. It was reported that field-independent students earned higher scores on both microteaching exercises and overall course score than did students with a field-dependent learning style. Garton and Cano concluded that students with field-independent learning styles appeared to be more adapted at teaching utilizing the problem-solving approach.

Marrison and Frick (1994) compared the extent to which academic and students' perceptions of traditional lecture and computer multimedia instruction was influenced by learning style. This study used the Group Embedded Figures Test to indicate learning style. The population of this study was undergraduate students enrolled in an introductory agricultural economics course (*n*=75). It was reported that 43% of the students were classified as field-dependent and 57% were field-independent. It was further reported that learning style had no significant effect on achievement or overall perception of instruction between traditional lecture and computer multimedia instruction.

Torres and Cano (1994) investigated the preferred learning style of students enrolled in the College of Agriculture at The Ohio State University. The study included a sample of 196 randomly selected senior students. Learning style was assessed using the Group Embedded Figures Test. It was reported that the students tended to be field-independent in learning style. Males preferred a field-independent style, however females were reported as preferring a field-dependent learning style. Additionally, differences in learning style preference were reported based on academic major. Students majoring in animal science, horticulture, agricultural education, food science, and dairy science tended to be field-independent. Students majoring in agricultural economics, agronomy, and agricultural communication tended to be field-dependent in their learning style.

Whittington and Raven (1995) described the preferred learning style of student teachers in agricultural education at the University of Idaho and Montana State University. The population for this census study consisted of students majoring in agricultural education at those two institutions (*n* = 31). This study used the GEFT to assess learning style. It was reported that 74% of the student teachers were field-independent in their learning style. Most males (66.7%) and all females (100%) reported field-independent as their preferred learning style. This learning style preference trend held when student teachers were compared based on age classifications.

Torres and Cano (1995) determined the learning styles of students enrolled in the College of Agriculture at The Ohio State University during the Autumn Quarter in 1992. A random sample of 196 students was selected from the population. Using the GEFT, Torres and Cano reported that 38.8% of the students were field-dependent and 61.2% were field-independent in their learning style. This study indicated that approximately 9% of the variance in critical thinking ability in students is uniquely accounted for by learning style.

Cano (1999) described the learning styles and academic performance of 1994 incoming freshman students enrolled in the College of Food, Agricultural, and Environmental Sciences at The Ohio State University (*n* = 187). Cano reported that 56% of the of the incoming freshman were field-independent, while 44% were field-dependent. Based on student academic majors, Cano stated that students who are field-independent may be attracted to “hard” sciences, and field-dependent learners may be attracted to “social” sciences.

Garton, Dyer, and King (2000) attempted to identify predictors of academic performance and retention of freshmen in the College of Agriculture, Food, and Natural Resources at the University of Missouri. The sample of this study consisted of an intact group of freshmen enrolled in a learning and development course (*n* = 245). It was reported that 56% of the students were field-independent in their learning style. Furthermore, 24% of the students were reported as field-neutral and 20% field-dependent. Garton, Dyer, and King reported that learners preferring a field-independent and field-neutral learning style exhibited greater academic performance, measured by GPA, than did field-dependent students.

Rudd, Baker, and Hoover (2000) explored the relationship between learning style and student disposition toward critical thinking. The sample for this study consisted of students in four classes in the College of Agriculture and Life Sciences at the University of Florida (*n* = 174). The researchers reported that most students (67%) were field independent in their learning style. No significant difference in student learning style was reported based on gender. Additionally, it was reported that no correlations existed between critical thinking and learning style.

Shih and Gamon (2002) investigated how students with different learning styles learned in web-based courses. This study included 99 students taking two non-major introductory biology courses. More than two thirds (69%) of the students were field-independent learners. It was reported that field-dependent students scored almost the same on the learning strategy scale as field-independent students.

Socioeconomic Status

Research on the effects of socioeconomic status, gender, and ethnicity has shown that it is difficult to discuss any one of these factors separately from the others when examining student achievement. Although socioeconomic status and/or ethnicity may appear to be meaningfully related to student achievement when examined individually (Fenwick, 1996; Wong & Alkins, 1999; Yellin & Koetting, 1991), this may be due to the fact that socioeconomic status and ethnicity are often coterminous (Abbott & Joireman, 2001). This means that students of some ethnic backgrounds also may be those who are unequally represented in lower socioeconomic groups.

Webster, Young, & Fisher (1999) conduced a secondary analysis of the database known as the Third International Mathematics and Science Study (TIMSS). The TIMSS sampled students from three population groups in 45 countries. For their study, the researchers selected thirteen-year-old students from Australia, Canada, England, and the United States. For this study, socioeconomic status was determined by using the variables of mother's and father's education, number of books in the home, and English speaking background. This study found that student gender and socioeconomic status accounted for a substantial degree of variance in student achievement. This study continued to state that most of that variance is explained at the student level, as opposed to the class or school level.

In a study conducted by Abbott and Joireman (2001), which analyzed 1999 and 2000 school-level data obtained from the Washington State Office of the Superintendent of Public Instruction, it was found that 12 - 29% of the variance in achievement, depending on the grade level of the student and the achievement measure given, was uniquely explained by low socioeconomic status. It was also found that student ethnicity explained on average almost 33% of the variance in low socioeconomic status. Therefore, this study found that the relationship between ethnicity and academic achievement is mostly indirect. It found that ethnicity is correlated to low socioeconomic status, which in turn is related to academic achievement. In this study socioeconomic status was defined as the percentage of students in a given school who were on free and reduced lunch. Furthermore, ethnicity was defined as the percentage of "White" students in a school.

Newsom-Stewart and Sutphin (1994) investigated tenth grade students' perceptions of agriculture, environmental science and the relationship of academic and agricultural courses. The population of this study consisted of students in twelve schools and technical centers (n = 1,253) across the state of New York. Using a researcher designed instrument, the researchers reported that tenth grade students tended to have a positive view of the importance of the fields of agriculture and environmental science. No significant difference was reported between the perceptions based on gender or ethnic characteristics. Additionally, the students, regardless of ethnicity and gender, reported that they felt agriculture was most closely related to science followed by mathematics, communication, and computers.

Hoffer, Rasinski, and Moore (1995) conducted an analysis of data collected in 1992 from the second follow-up survey of the National Education Longitudinal Study of 1988. The students included in this study were 8th graders in 1988. Most of the students (85%) were high school seniors when this data was collected. The focus of this study was to examine student's coursetaking patterns in high school and achievement in mathematics and science. One of the findings of this study was that there were no differences in the number of courses taken in mathematics or science based on gender. A difference was found between ethnic groups with Asians completing the most courses and Hispanic and

Africa-American students completing the fewest. However, when examining the data based on socioeconomic status of the students' families, the difference in number of courses taken between ethnic groups disappeared. Therefore, socioeconomic status was found to be a key factor influencing the number of science and mathematics courses taken in high school. Furthermore, the number of courses taken in each of the subject-matter areas was found to directly impact achievement in both areas. Guskey (1997) investigated the relationship between socioeconomic variables and school-level achievement results on the Kentucky Instructional Results Information System (KIRIS). Information was collected over a three year period from 49 schools within one school district. This study found that the correlations between percent of students in a school qualifying for free or reduced lunch benefits and percent of minority students were .82 for elementary schools, .92 for middle schools, and .96 for high schools. This study also found that the socioeconomic indicator of qualification for free or reduced lunch benefits explained much of the variation in level of achievement in a high-stakes, performance-based student assessment program.

Lubienski (2001) examined the disparities between White and African-American students' mathematical achievement. Data was drawn from the 1990 and 1996 National Assessment of Educational Progress (NAEP). The NAEP samples consist of several thousand 4th, 8th, and 12th graders from both public and private schools. Socioeconomic status for this study was constructed using the variables of resources in the home (i.e. books, encyclopedia, newspapers) and parental education. No significant difference in NAEP scores was found between the achievement gains of male and female students. In examining difference in achievement scores across ethnicity, it was found that White students scored significantly higher than did African American students. Furthermore, when socioeconomic status and ethnicity were examined together a significant difference was found between both ethnic group and socioeconomic status. It was found that the lowest socioeconomic status White students scored equal to or higher than the highest socioeconomic status African American students.

Presage Variables

The presage variables described by Duncan and Biddle (1974) were controlled in this study through research design or statistical measures. An effort was made in the research design to provide similar student groups for each teaching method. The importance of this variable should not be seen as lacking. However, the focus of this study was on the other variables found in the model.

Chapter Summary

The purpose of this chapter was to describe the theoretical and conceptual frameworks, and delineate the empirical research pertinent to this study. Research literature regarding each of the variables to be studied was examined to gain an understanding of previous studies.

In general, the findings regarding the effect of teaching approach on student content knowledge achievement are at best mixed. The subject matter approach was found to be commonly used as the “control” in studies that compared teaching approaches.

Research in agricultural education is mixed as to the effect of learning style on student content knowledge achievement. Furthermore, studies that have described the learning style of students in agricultural education at both the secondary and post-secondary level are mixed as to learning style preference of students. Therefore, continued research is needed in this area.

CHAPTER 3
METHODS

Chapter 1 described the rationale for evaluating the effects of investigative laboratory integration in secondary agricultural education courses. The primary purpose of this study was to determine the effect of investigative laboratory integration on student content knowledge achievement and science process skill development across different learning styles.

Chapter 2 described the theoretical and conceptual frameworks, and delineated the empirical research relevant to this study. Included in this chapter were reviews of literature and research pertaining to the following:

- context variables
    - learning style
    - gender
    - ethnicity
- process variables
    - subject matter approach
    - experiential learning
    - inquiry-based approach
- presage variables
- product variables
    - content knowledge achievement
    - science process skills

In this chapter, methods used to address the research questions are discussed. This chapter reports the procedures, research design, population and sample, instrumentation, data collection procedures, and data analysis techniques.

The independent variable in this study was the teaching method used in the agricultural education classes. Treatment groups utilized one of three levels of treatment:

subject matter approach without laboratory experimentation, subject matter approach with prescriptive laboratory experimentation, subject matter approach with investigative laboratory experimentation. The dependent variables in this study were student content knowledge achievement and science process skill level. Characteristics that were treated as antecedent variables were student learning style, ethnicity, and gender.

Covariates were used to adjust group means in order to compensate for previous knowledge in the subject matter. These covariate measures included pretests for the unit of instruction.

Research Design

This study utilized a quasi-experimental design. This design was selected due to the fact that random assignment of subjects to treatment groups was not possible. Therefore, intact groups were used. The study followed a variation of the nonequivalent control group design (Campbell & Stanley, 1963). In this study there was no group that received no treatment, as is the definition of a true control group as defined by Campbell and Stanley. However, Gall, Borg, and Gall (1996) stated that all groups may receive a treatment in the nonequivalent control group design. They state that the only essential features of this design are nonrandom assignment of subjects to groups and administration of a pretest and posttest to all groups. The variation of the nonequivalent control group design appears as follows:

$$\begin{array}{ccc} O_1 & X_1 & O_2 \\ \hdashline O_1 & X_2 & O_2 \\ \hdashline O_1 & X_3 & O_2 \end{array}$$

The first observation (O_1) consisted of a content knowledge pretest given to each participant to determine prior knowledge of the subject matter. Also, administered at this time were the Group Embedded Figures Test (GEFT) and the Test of Integrated Process Skills (TIPS). All activities included in the first observation (O_1) were conducted approximately one week prior to the beginning of instruction in the selected unit.

At the initial visit to each school, student demographic data were requested from the school student services department. Student confidentiality was maintained throughout this process by assigning each student an identification number. All records were sent to the researcher with this identification number and not student names.

One of three treatments was utilized with each group. There were two experimental treatments (X_1 and X_2). Each treatment lasted 4 – 6 weeks. The first experimental treatment (X_1) consisted of the subject matter approach with prescriptive laboratory experimentation activities. The second experimental treatment (X_2) consisted of the subject matter approach with investigative laboratory experimentation. The contrasting treatment (X_3) was the subject matter approach without laboratory experimentation.

The second observation (O_2) occurred directly following the treatment. It consisted of a content knowledge achievement posttest for the unit of instruction and the Test of Integrated Process Skill II, a parallel version of the science process skill instrument administered during the first observation (O_1).

The basic threats to internal validity identified by Campbell and Stanley (1963) include history, maturation, testing, instrumentation, regression, subject selection, mortality, and interaction effects. The nonequivalent control group research design controls all of the threats except regression and interaction. The risk of regression, however a concern whenever a pretest-posttest procedure is used to determine the amount of change as result of a treatment, can be minimized if subjects are not selected based on extreme scores (Campbell & Stanley, 1963). Therefore, since none of the groups were selected via extreme scores of any kind, regression effects should not be a serious threat to internal validity in this study.

Gall, Borg, and Gall (1996) state that the main threat posed by interaction in this type of research design is the possibility that differences found in posttests are due to preexisting group differences, rather than to treatment effects. Therefore to address the threat of interaction to internal validity, several steps were taken. The use of multiple classroom settings helped to reduce the risk of interaction. Also, using the covariates of content knowledge achievement pretest and science process skill pretest scores to statistically adjust the means on the posttest addressed this concern.

In conducting a study of this kind, factors in addition to those affecting internal validity must be controlled. The factor of individual teaching ability of the teachers involved in the study was addressed by the use of a number of different teachers within each treatment. Additionally, the content selected to be delivered in the treatments was deemed appropriate by a panel of experts to be delivered via all of the teaching methods included in the study. All teachers involved in the study participated in professional development activities to instruct them on how to properly deliver each treatment as recommended by Boone (1988). These professional development activities were conducted by the researchers and ranged from one to two hours in length. In addition to individual instruction on the teaching method, each teacher involved in the study received a researcher developed videotape containing further instruction on the teaching method and general information about the study.

The unit of instruction on plant germination was selected from the Agriscience Foundations I curriculum published by the Florida Department of Education. The three treatments were randomly assigned to the classes. To ensure proper utilization and adherence to the assigned treatment, each teacher presentation was audio taped and analyzed by the researcher.

An additional threat to internal validity was posed by the selection of participants for the study. This included the teachers, classes, and students involved in this study. The sample was selected based upon the ability of the teacher to effectively deliver all three of the teaching approach treatments. Whereas treatments were randomly assigned to classes, data were collected on individual students. This threat to internal validity, however much a concern, is unavoidable as random selection and assignment of participants was not possible in the high school setting.

Procedures

Following the suggestion made by Boone (1988) for conducting teaching method studies using teachers to deliver the treatment, precautions were taken to ensure teacher conformity to the assigned teaching approach. Prior to beginning the study, teachers were provided professional development on their assigned teaching method. All materials needed by the teacher to deliver the treatment (lesson plans, handouts, assessment instruments, etc.) were provided by the researcher.

As mentioned previously, the teachers audio recorded each lesson. At the conclusion of the treatment, the researcher analyzed the audio recordings to determine the level to which the treatment was administered. The researcher designed Treatment Delivery Analysis Scoresheets (Appendix A) were used. Following procedures similar to those of Dyer (1995), the first class period and two other randomly selected classes were evaluated. Tapes were scored on a 10-point scale based upon the teacher's adherence to the assigned teaching approach. It was determined a priori that a mean of greater than 6.0 would be necessary to accurately reflect the respective teaching approach. It was determined a priori that students in classes in which the assigned teaching approach had not been properly utilized as determined by the Treatment Delivery Analysis Scoresheet, would be removed from the sample.

Approximately one week prior to instruction, students completed the activities included in the first observation of the research design. This included three assessments. The first of which was a content knowledge pretest to determine their entry level of knowledge. The Group Embedded Figures Test (GEFT) was administered to measure student learning styles. The Test of Integrated Process Skills (TIPS) was used to measure the students' entry level of science process skill.

It was determined a priori that in order to be deemed to have received the treatment, a student must be in attendance at least 80 percent of the days in which the treatment was being delivered. Students not meeting this requirement were removed from the study.

Following the instruction, students were administered the content knowledge achievement posttest and the Test of Integrated Process Skill II, a parallel version of the science process skill instrument administered during the first observation. At the conclusion of all testing, students and teachers were debriefed concerning their participation in the study.

Population

The population for this study was Florida students enrolled in an introductory agriscience course. A purposive sample was selected based upon the ability of the teacher to effectively deliver all three of the teaching approach treatments. All teachers included in this study were identified as high quality teachers by the agricultural education faculty at the University of Florida. This designation was made based upon teaching observations made by faculty. In addition, these teachers have served as supervisors to agricultural education student teaching interns. Each teacher was randomly assigned a treatment (teaching method) group.

Sample Size

The formula suggested by Hays (1973) was used to determine the size of the sample in order to ensure the ability to properly measure the variables of the study, yet avoid finding significance because of inflated sample size. A sample size was selected as to limit the probability of committing a Type I error to .05, achieve a desired power of .90, and to be able to detect variances greater than .10 in the dependent variables due to the independent variable. The following formula was used to determine sample size

$$n = 2\ [Z_{(1-\alpha/2)} - Z_{\beta}]^2 + \Delta^2$$

where $Z_{(1-\alpha/2)}$ equals the z score for the alpha level desired (.05), Z_{β} equals the z score for the desired power (.90), and Δ equals the effect size in standard deviation units. Δ is computed using the formula

$$\Delta = 2\sqrt{(w^2)}\ /\ \sqrt{(1 - w^2)}$$

where w^2 represents the amount of variance of the dependent variable accounted for by the independent variable. The calculations for this study, using the above formulas are

$$\Delta = 2\ \sqrt{[.10/(1-.10)]} = .66$$

$$n = 2[1.96 - (-1.64)]^2\ /\ .66^2 = 59.5$$

It was determined, using this formula that a minimum of 60 students in each treatment were required to achieve the appropriate sample size. Based on the findings of Flowers

(1986), Boone (1988), and Dyer (1995), this type of study experiences a mortality rate of approximately 50%. Therefore, this number was doubled for each treatment in order to offset effects of mortality.

Instrumentation

The researcher developed the instrument used to collect data for the dependent variable of content knowledge achievement. The Test of Integrated Process Skills (Dillashaw & Okey, 1980) was used to measure science process skill. The Group Embedded Figures Test (Witkin, Oltman, Raskin, & Karp, 1971) was used to measure the antecedent variable of learning styles. Data concerning the antecedent variables of ethnicity, gender, and other student characteristics were reported to the researcher by the school's student services department from student records. Lesson plans for the unit of instruction were created by the researcher to serve as parameters for the treatments.

Unit of Instruction Plans

Instructional plans appropriate to the teaching methods used were developed using information from *Biological Science Applications in Agriculture* (Osborne, 1994). The content of the unit was designed to address the plant science portion of Florida Student Performance Standard 06.0 for the Agriscience Foundations I course (Florida Department of Education, 2002). The lessons within this unit were designed to take five to six weeks to complete. The plant science subject matter to be taught was consistent among all three sets of instructional plans. All students in the introductory agriscience classes included in the study were taught all lessons within the unit of instruction. However, approximately one-third of the students received the instruction utilizing the subject matter approach with prescriptive laboratory experimentation activities, one-third received the instruction utilizing the subject matter approach with investigative laboratory experimentation, and one-third received the instruction using the subject matter approach without laboratory experimentation. The instructional plans (Appendix B) were evaluated for content validity by a panel of experts from the Agricultural Education and Communication Department at the Univeristy of Florida and local high schools.

Content Knowledge Achievement Assessment Instruments

In order to measure student prior content knowledge and content knowledge achievement, the researcher designed a content knowledge pretest (Appendix C) and a content knowledge achievement posttest (Appendix D). All tests were similar in design and difficulty. Teaching objectives were used as a guide in constructing these parallel assessment instruments. A panel of experts from the Agricultural Education and Communication Department at the University of Florida and local high schools was used to determine face and content validity of the instruments. Assessment instruments were evaluated by the panel of experts to verify that each objective included in the lesson plans were properly addressed in the instrument.

Learning Styles Inventory

The Group Embedded Figures Test (GEFT) (Witkin et al., 1971) was used to assess student learning style. The validity of this instrument was established by Witken et al. In addition, a Spearman-Brown reliability coefficient of .82 was reported by the developers of the instrument.

Science Process Skill Assessment Instrument

Like the Group Embedded Figures Test, the Test of Integrated Process Skills (TIPS) is considered a standardized test. The TIPS was designed to assess proficiency in the science process skills associated with planning, conducting, and interpreting results from investigations (Dillashaw & Okey, 1980). Dillashaw and Okey stated that this instrument is a valid and reliable measure of process skill achievement for students in the 7th to 12th grades. Reliability of the test was found using Cronbach's alpha to be .89. The mean item discrimination of the instrument was reported as .40. In addition the developers of this instrument reported a readability index of 9.2 for this instrument.

Treatment Delivery Analysis Scoresheet

To ensure that teachers involved in this study were following the correct teaching approach, teachers were asked to audiotape each class period in which the treatment was being administered. An instrument was developed by the researcher to be used in analyzing those tapes (Appendix A). A panel of experts consisting of the agriculture teacher education faculty of the Agricultural Education and Communication Department at the University of Florida evaluated the instrument for content validity.

Analysis of Data

Data were analyzed using the SPSS® version 12.0 for Windows® software package. Analysis of the first objective involved descriptive statistics and included frequencies, means, and standard deviations. The second two objectives were examined using backward regression analyses. All hypotheses were tested using multivariate analysis of covariance (MANCOVA). Univariate analysis of covariance (ANCOVA) was used as a follow-up procedure, when appropriate.

Agresti and Finlay (1997) stated that these procedures are appropriate when analyzing two or more dependent variables (content knowledge achievement and science process skill) while statistically controlling one or more variables (teaching approach, learning style, student demographic data). These procedures also allow the researcher to control the overall alpha level and decrease the chance of committing a Type I error.

Chapter Summary

In this chapter, the methods used to address the research questions were discussed. This chapter reported the procedures, research design, population and sample, instrumentation, data collection procedures, and analysis of data.

The independent variable in this study was reported as the teaching method used in the agricultural education classes. The treatments investigated in this study were identified as: subject matter approach without laboratory experimentation, subject matter approach with prescriptive laboratory experimentation, and subject matter approach with investigative laboratory experimentation. The dependent variables in this study were identified as student content knowledge achievement and science process skill level. Characteristics which were treated as antecedent variables were student learning style, ethnicity, and gender.

It was reported that covariates were used to adjust group means in order to compensate for previous knowledge in the subject matter and the individual learning ability of the students. These covariate measures included pretests for the unit of instruction.

It was reported in this chapter that the design of this study was a quasi-experimental design referred to as nonequivalent control group design by Campbell and Stanley (1963). Threats to validity in this study were discussed.

Data collected were identified as pretest content knowledge scores, content knowledge achievement scores, pre- and post- treatment science process skill scores (as measured by the TIPS instrument), student learning styles (as measured by the GEFT instrument), student attendance records, and audiotapes of classes. Method of data analysis used were noted as multivariate analysis of covariance, univariate analysis of covariance, means, standard deviations, correlations, frequencies, percentages, and post hoc analyses.

CHAPTER 4
RESULTS AND DISCUSSION

Chapter 1 described the rationale for evaluating the effects of investigative laboratory integration in secondary agricultural education courses. The primary purpose of this study was to determine the effect of investigative laboratory integration on student content knowledge achievement and science process skill achievement across learning styles, gender, and ethnicity.

Chapter 2 described the theoretical and conceptual frameworks and delimited the empirical research relevant to this study. The study was framed around Mitzel's theory that the outcome of learning (product) is influenced by the context variables that students contribute to the educational process, the presage variables contributed by the teacher, and the process variables contributed by the learning environment. Included in this chapter were reviews of literature and research pertaining to the following:

- context variables
    - learning style
    - gender
    - ethnicity
- process variables
    - subject matter approach
    - experiential learning
    - inquiry-based approach
- presage variables
- product variables
    - achievement
    - science process skills

In Chapter 3 the methods used to address the research questions were discussed. This chapter reported the procedures, research design, population and sample, instrumentation, data collection procedures, and analysis of data.

The independent variable in this study was the teaching method used in the agricultural education classes. Treatment groups utilized one of three levels of treatment: subject matter approach without laboratory experimentation, subject matter approach with prescriptive laboratory experimentation, subject matter approach with investigative laboratory experimentation. The dependent variables in this study were student content knowledge achievement and science process skill level. Characteristics that were treated as antecedent variables were student learning style, ethnicity, and gender.

Covariates were used to adjust group means in order to compensate for previous knowledge in the subject matter. These covariate measures included pretests for the unit of instruction.

It was reported in Chapter 3 that the design of this study was a quasi-experimental design referred to as nonequivalent control group design by Campbell and Stanley (1963). Threats to validity in this study were discussed. Data to be collected were pretest scores, content knowledge achievement scores, science process skill scores (as measured by the TIPS instrument), student learning styles (as measured by the GEFT instrument), student attendance records, and audio tapes of classes. Data were analyzed using a multivariate analysis of covariance, univariate analysis of covariance, means, standard deviations, correlations, frequencies, percentages, and post hoc analyses.

This chapter presents the findings obtained by this study. The results address the objectives and hypothesis of the study in determining the influence of learning styles, gender, and ethnicity on content knowledge achievement and science process skill ability.

The purposive sample used in this study consisted of students enrolled in introductory agriscience courses in Florida. A total of ten different schools across Florida were selected to participate in this study. A total of 501 students were enrolled in classes in the selected schools from which data were collected (see Table 4-1).

Table 4-1 Study Treatment Group Membership Totals

Treatment Group	# of Schools	# of Students
Subject Matter Only	3	168
Prescriptive Laboratory	3	151
Investigative Laboratory	4	182
Total	10	501

No data were received from one participating school in the subject matter group. Repeated contacts were made with the participating teacher, however, since no data were obtained, the students in this class were removed from the study. Likewise, one of the participating teachers in the investigative laboratory group left teaching during the study treatment. Therefore, students in this class were also removed from the study. Additionally, one teacher in the investigative group was determined to not have fully delivered the treatment. This determination was made by the researcher using the Treatment Delivery Analysis Scoresheet to review the audiotapes submitted by the participating teacher. Since it was determined that the treatment was not adequately administered, the students in this class were likewise removed from the study. This mortality resulted in the sample size being reduced to 352 students. This equates to a

29.7% mortality rate for this study. Previous experimental studies using intact classes reported similar or higher mortality rates.

As outlined in Chapter 3, data were collected at various points throughout the treatment. Content knowledge was assessed both prior to, and following, the treatment. The response rate for each collection was 70.7% and 62.5%, respectively (see Table 4-2). Likewise, the science process skill ability of the participants was measured using the Test of Integrated Process Skills [TIPS] (Dillashaw & Okey, 1980) pre- and post-treatment. The response rates for pre- and post-test TIPS administration were 79.8% and 50.9%, respectively. Learning style data were collected with a response rate of 81.0%.

Table 4-2 Response Rates for Data Collection Components (*n* = 352)

Data Collection Component	*n*	Response Rate
Content Knowledge Pretest	249	70.7%
Content Knowledge Posttest	220	62.5%
Science Process Skills Pretest	281	79.8%
Science Process Skills Posttest	179	50.9%
Learning Styles Instrument	285	81.0%

Prior to data analysis, post hoc reliability was established for each data collection instrument used in the study. All instruments consisted of data with items measured as right or wrong. Therefore, the instruments were analyzed for reliability using the Kuder-Richardson 20 formula (Gall, Borg, & Gall, 1996). Posttest instruments for both the content knowledge achievement and science process skill were parallel forms to the pretest instruments.

A reliability coefficient of .92 was determined for the content knowledge achievement instruments (see Table 4-3). Analysis of reliability of the science process skill instrument yielded a coefficient of .72.

Table 4-3 Post-Hoc Instrument Reliability

Instrument	Reliability
Content Knowledge Achievement	.92
Science Process Skill	.72

The length of time needed for teachers to deliver the instruction that was part of this study varied between groups (see table 4-4). The average number of minutes of instruction across all groups was 1542. The teachers in the subject matter only and prescriptive laboratory groups averaged 1410 and 1392 minutes of instruction, respectively. The longest reported time spent on activities included in this study was reported by the investigative laboratory group (*M* = 1900).

Table 4-4 Average Length of Treatment

Treatment Group	# of Schools	Mean Minutes of Instruction
Subject Matter Only	2	1410.0
Prescriptive Laboratory	3	1391.7
Investigative Laboratory	2	1900.0
Total	7	1542.1

Objective One: Describe the Learning Styles, Ethnicity, and Other Demographic Characteristics of Participants in this Study.

Grade Level

Of the 322 participants that reported grade level data, 62.7% (*n* = 202) were in the ninth grade (see Table 4-5). The remainder of the participants were in either the tenth grade (*n* = 64, 19.9%), eleventh grade (*n* = 39, 12.1%), or twelfth grade (*n* = 17, 5.3%). The grade level breakdown by treatment groups varied from that of the overall sample (see Figure 4-1). Almost 80% of the students in the investigative laboratory group were in the ninth grade as compared to only 49% in the prescriptive laboratory group. Therefore, results should be interpreted with caution in regards to grade level.

Table 4-5 Participant Grade Level (*n*= 322)

	Treatment Group							
	SM		PL		IL		Total	
Grade Level	*n*	%	*n*	%	*n*	%	*n*	%
Ninth	47	62.7	66	48.9	89	79.5	202	62.7
Tenth	19	25.3	37	27.4	8	7.1	64	19.9
Eleventh	9	12.0	22	16.3	8	7.1	39	12.1
Twelfth	0	0.0	10	7.4	7	6.3	17	5.3

Note. SM = Subject Matter Group; PL = Prescriptive Laboratory Group; IL = Investigative Laboratory Group

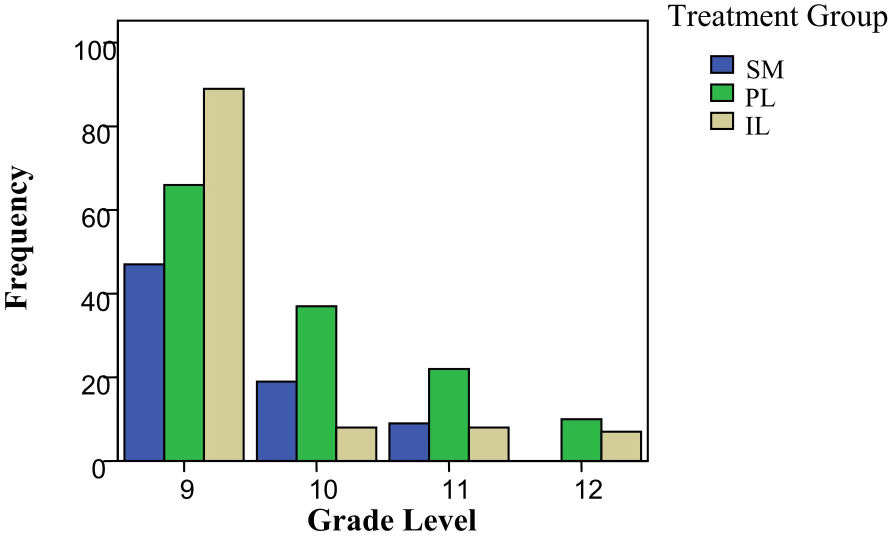

Figure 4-1 Distribution of Participant Grade Level

Ethnicity

Participant ethnicity was categorized into the groups of Black, White, non-Hispanic, Hispanic, and Other. The majority of students participating in this study categorized themselves as White (56.0%). The second largest group was Hispanic (34.5%) followed by Black (7.9%) and Other (1.6%). The ethnic make-up of each of the treatment groups varied from that of the entire sample (see Table 4-6). Approximately 47% of the students in the subject matter group were Hispanic as compared to only 23%

in the investigative laboratory group. Therefore, results should be interpreted with caution in regards to ethnicity.

Table 4-6 Participant Ethnicity (*n* = 316)

	Treatment Group							
	SM		PL		IL		Total	
Ethnicity	*n*	%	*n*	%	*n*	%	*n*	%
Black	5	6.8	12	9.0	8	7.4	25	7.9
White, non-Hispanic	33	44.6	71	53.0	73	67.6	177	56.0
Hispanic	35	47.3	49	36.6	25	23.1	109	34.5
Other	1	1.4	2	1.5	2	1.9	5	1.6

Note. SM = Subject Matter Group; PL = Prescriptive Laboratory Group; IL = Investigative Laboratory Group

Gender

The majority of participants in this study (66.5%) was male. Treatment groups closely followed the same gender makeup as did the entire sample (see Table 4-7).

Table 4-7 Participant Gender Distribution (*n* = 322)

	Treatment Group							
	SM		PL		IL		Total	
Gender	*n*	%	*n*	%	*n*	%	*n*	%
Male	55	73.3	87	64.9	72	63.7	214	66.5
Female	20	26.7	47	35.1	41	36.3	110	33.5

Note. SM = Subject Matter Group; PL = Prescriptive Laboratory Group; IL = Investigative Laboratory Group

Learning Style

The Group Embedded Figures Test (GEFT) (Witkin et al., 1971) was used to assess student learning style. According to the authors of the GEFT, individuals may be classified as either field-dependent or field-independent based upon their score on this instrument. Possible scores range from 0 to 18, with the national grand mean being reported by Witkin et al. as 11.3. Those individuals with scores below this average are considered field-dependent. Individuals with scores above 11.3 are considered field-independent. However, Garton and Raven (1994) reported a third category of learners. These learners score toward the center of this bipolar scale. Dyer (1995) suggested that for high school students the following scale (Figure 4-2) should be used to categorize student learning styles.

Abstract | | Concrete

0 8	9 11	12 18
Field-Dependent	Field-Neutral	Field-Independent

Figure 4-2 GEFT Score Interpretation Guidelines

The mean GEFT score for respondents in this study was 7.6 (*SD* = 4.74). Figure 4-3 shows the distribution of GEFT scores.

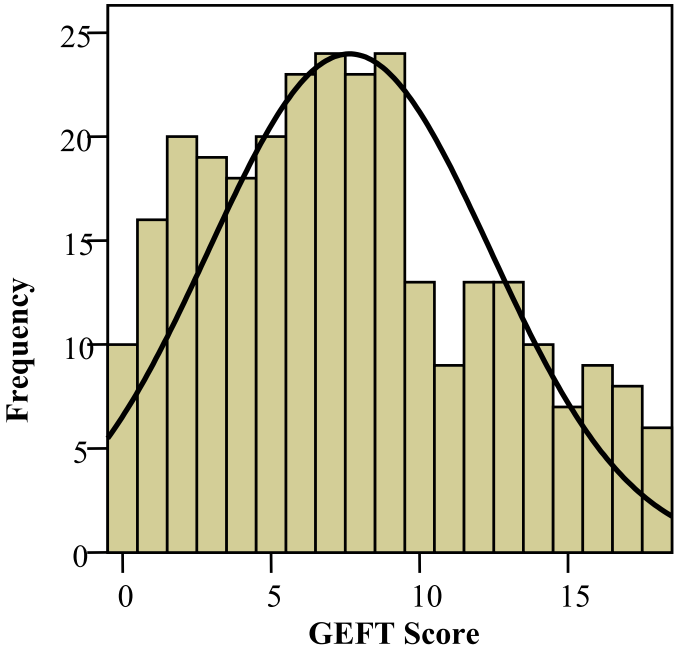

Figure 4-3 GEFT Score Distribution

A majority (60.7%) of students was categorized as field-dependent. The next largest group was field-independent learners (23.2%), followed by field-neutral learners

(16.1%) (see Table 4-8). The learning style makeup of each of the treatment groups was similar to that of the entire sample (see Figure 4-4).

Table 4-8 Participant Learning Style Distribution by Treatment Group (*n* = 285)

	Treatment Group							
	SM		PL		IL		Total	
Learning Style	*n*	%	*n*	%	*n*	%	*n*	%
Field-Dependent	42	59.2	73	60.3	58	62.4	173	60.7
Field-Neutral	13	18.3	18	14.9	15	16.1	46	16.1
Field-Independent	16	22.5	30	24.8	20	21.5	66	23.2

Note. SM = Subject Matter Group; PL = Prescriptive Laboratory Group; IL = Investigative Laboratory Group

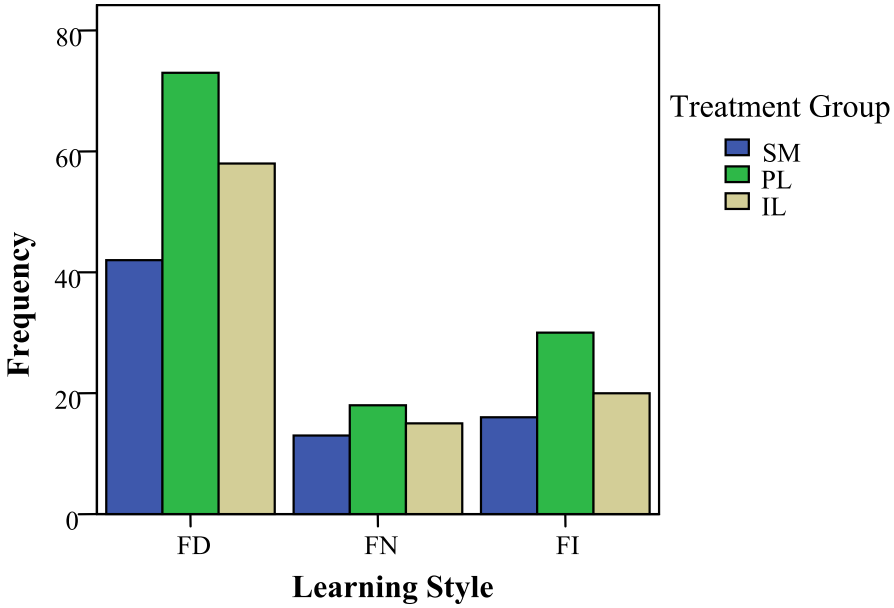

Figure 4-4 Learning Styles by Treatment Group

An exploration of learning styles by grade level revealed that the majority of students in all grade levels were field-dependent in their learning style (see Table 4-9). The percentage of field-neutral and field-independent learners increased for eleventh and twelfth grade students. With the exception that approximately 24% of the students in the eleventh grade were field-neutral as compared to no students having a field-neutral learning style in the twelfth grade. Therefore, results should be interpreted with caution in regards to learning style across grade level.

Table 4-9 Participant Learning Style Distribution by Grade level (*n* = 284)

	Grade Level							
	9		10		11		12	
Learning Style	*n*	%	*n*	%	*n*	%	*n*	%
Field-Dependent	114	62.0	32	60.4	18	54.5	8	57.1
Field-Neutral	30	16.3	8	15.1	8	24.2	0	0.0
Field-Independent	40	21.7	13	24.5	7	21.2	6	42.9

An analysis of learning styles based upon student gender is shown in Table 4-10. The majority of both male (58.8%) and female (63.5%) students were field-dependent in their learning style. Approximately the same percentage of males and females were also categorized as field-neutral (17.6% and 13.5%, respectively) and field-independent (23.5% and 22.9%, respectively).

Table 4-10 Participant Learning Style Distribution by Gender (*n* = 283)

	Gender			
	Male		Female	
Learning Style	*n*	%	*n*	%
Field-Dependent	110	58.8	61	63.5
Field-Neutral	33	17.6	13	13.5
Field-Independent	44	23.5	22	22.9

Content Knowledge Achievement

Each student’s content knowledge achievement was determined using the researcher developed content knowledge achievement pretest and posttest instruments. The maximum possible score on these parallel instruments was 50. Pretest data were collected from 249 participants with an overall mean of 16.39 (*SD* = 5.04) (see Figure 4-5). The mean pretest scores by treatment group are shown in Table 4-11. The subject matter group reported the highest pretest mean (*M* = 18.09, *SD* = 5.07). The prescriptive laboratory group and the investigative laboratory group had similar mean content knowledge pretest scores (*M* = 15.98, *SD* = 4.93; *M* = 15.47, *SD* = 4.86; respectively).

Posttest data were collected from 220 students. The overall mean of the content knowledge achievement posttest was 20.59 (*SD* = 6.79) (see Figure 4-6). The highest posttest score mean recorded was the subject matter group. This group had a mean of 24.63 (*SD* = 5.93). The posttest means for the prescriptive laboratory group and the investigative laboratory group were 18.30 (*SD* = 6.00) and 20.53 (*SD* = 7.16) respectively (see Table 4-11).

Table 4-11 Instrument Scores by Treatment Group

	Treatment Group							
	SM		PL		IL		Total	
Instrument	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Content Knowledge Pretest	18.09	5.07	15.98	4.93	15.47	4.86	16.39	5.04
Content Knowledge Posttest	24.63	5.93	18.30	6.00	20.53	7.16	20.59	6.79
Science Process Skills Pretest	16.17	5.38	16.39	5.58	14.01	5.73	15.57	5.66
Science Process Skills Posttest	18.62	6.17	14.34	6.66	15.59	6.07	15.81	6.66
Content Knowledge Gain Score[a]	6.27	4.84	1.72	6.36	5.04	5.89	3.93	6.15
Science Process Skill Gain Score[a]	2.02	5.19	-2.50	6.20	3.20	5.80	-0.17	6.33

Note. SM = Subject Matter; PL = Prescriptive Laboratory; IL = Investigative Laboratory
[a] Gain score = Posttest score minus pretest score

The content knowledge gain score was calculated by subtracting the pretest score from the posttest score. The overall mean content knowledge gain score as reported in Table 4-11 was 3.93 (*SD* = 6.15). The largest content knowledge skill gain score was reported for the subject matter group of 6.27 (*SD* = 4.84). The investigative laboratory group had a mean content knowledge skill gain score of 5.04 (*SD* = 5.89). The prescriptive laboratory group reported a gain score of 1.72 (*SD* = 6.36). A distribution of content knowledge skill gain scores may be found in Figure 4-7.

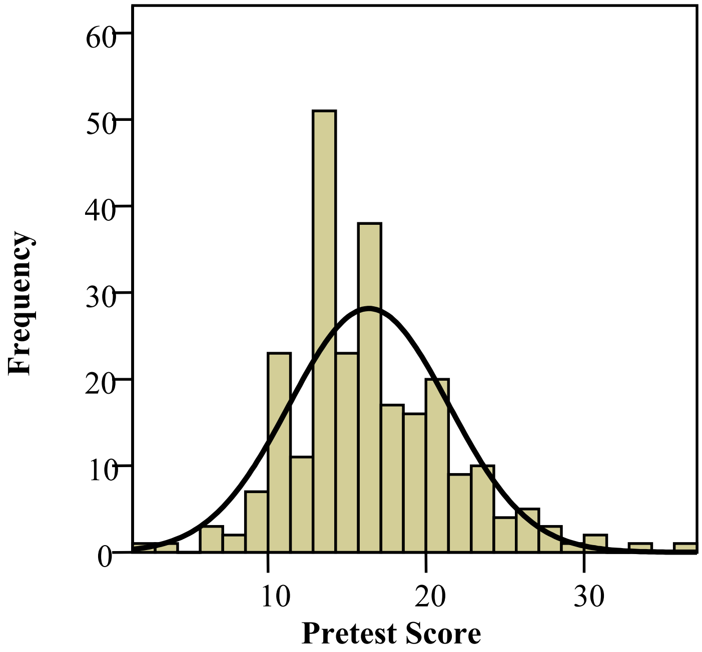

Figure 4-5 Distribution of Participant Content Knowledge Achievement Pretest Scores

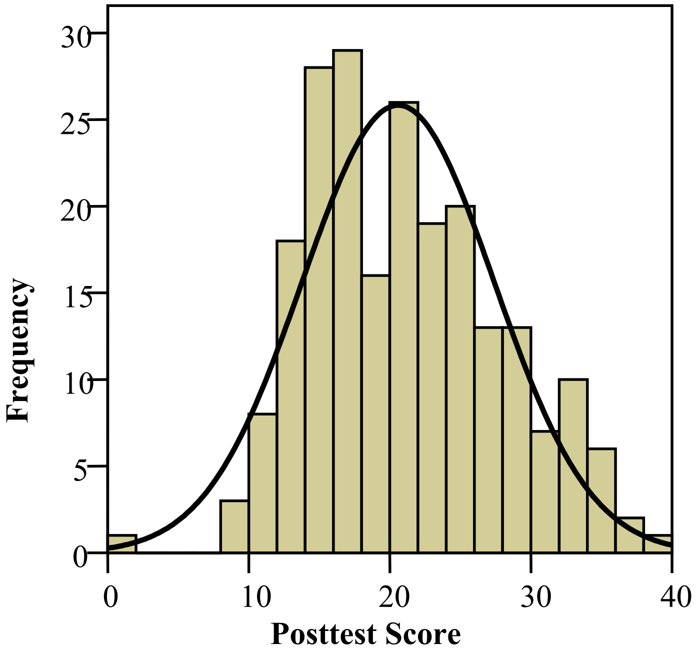

Figure 4-6 Distribution of Participant Content Achievement Posttest Scores

Science Process Skill

The Test of Integrated Process Skills was used to determine the science process skill level of students both prior to (pretest) and following (posttest) the treatment. The overall mean of the pretest was 15.57 (*SD* = 5.66) of a possible 36 (see Table 4-11). The mean pretest science process skill scores were similar between the subject matter (*M* = 16.17, *SD* = 5.38) and prescriptive laboratory groups (*M* = 16.39, *SD* = 5.58). The mean pretest score for the investigative group was slightly lower at 14.01 (*SD* = 5.73). A distribution of science process skill pretest scores may be found in Figure 4-8.

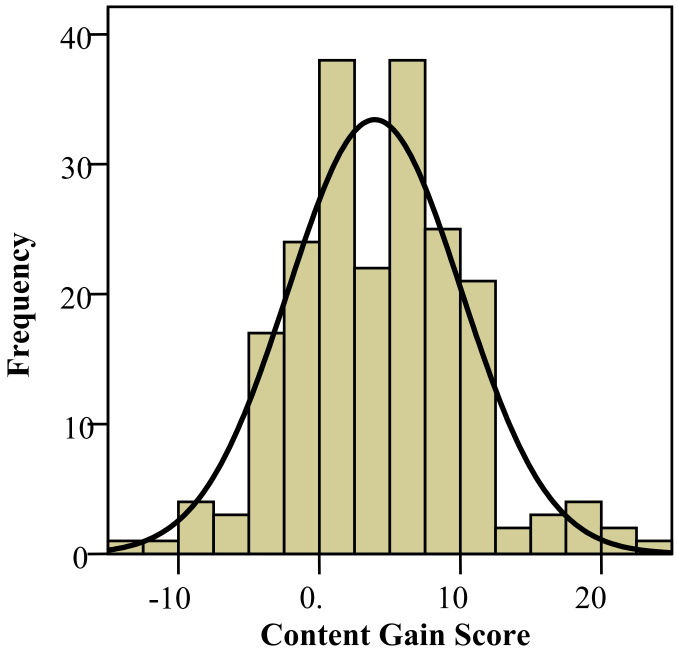

Figure 4-7 Distribution of Participant Content Knowledge Gain Scores

The overall mean for the science process skills posttest was 15.84 (*SD* = 6.66). The highest posttest score mean of 18.62 (*SD* = 6.17) was recorded for the subject matter group. The prescriptive laboratory and investigative laboratory groups reported means of 14.34 (*SD* = 6.66) and 15.59 (*SD* = 6.07) respectively (see Table 4-11). A distribution of science process skill posttest scores may be found in Figure 4-9.

The science process skill gain score was calculated by subtracting the pretest score from the posttest score. The overall mean science process skill gain score, as reported in Table 4-11, was -0.17 (*SD* = 6.33). The largest science process skill gain score was reported for the investigative laboratory group of 3.20 (*SD* = 5.80). The subject matter group had a mean science process skill gain score of 2.02 (*SD* = 5.19). The prescriptive laboratory group reported a gain score of -2.50 (*SD* = 6.20). A distribution of science process skill gain scores may be found in Figure 4-10.

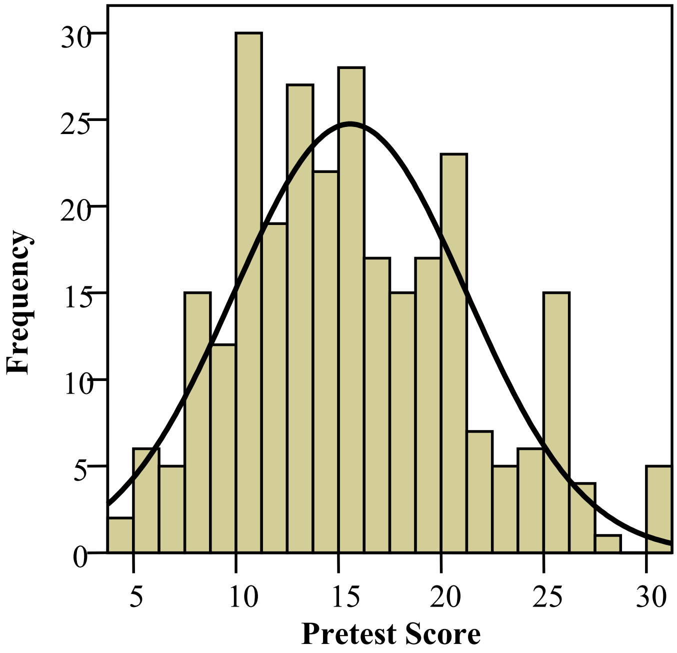

Figure 4-8 Distribution of Participant Science Process Skill Pretest Scores

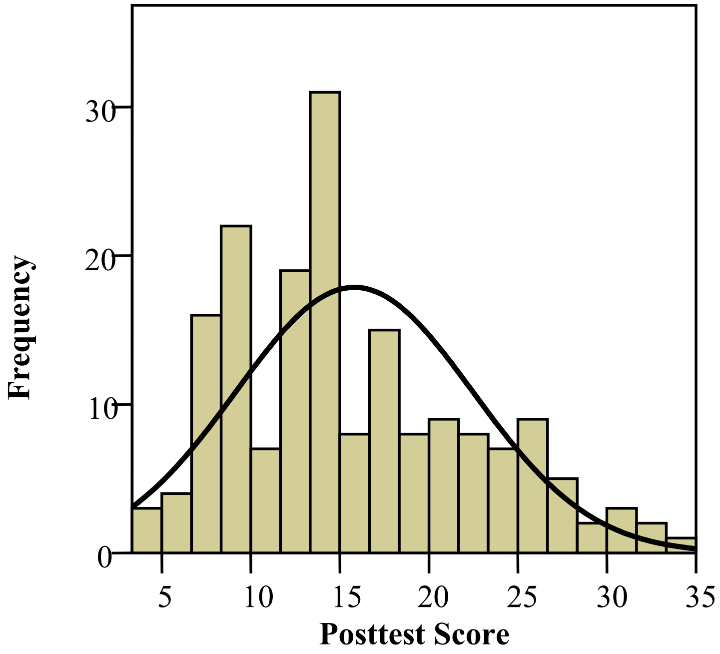

Figure 4-9 Distribution of Participant Science Process Skill Posttest Scores

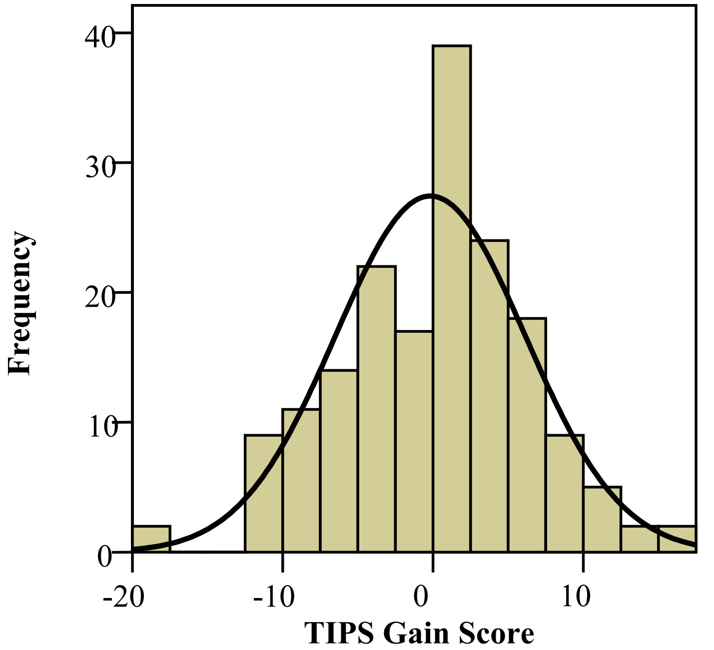

Figure 4-10 Distribution of Participant Science Process Skill Gain Scores

Relationships Between Variables

Prior to any inferential analysis of the data, all variables were examined for correlations. For the purpose of discussion, the terminology proposed by Miller (1994) was used to indicate the magnitude of the correlations. According to Miller, correlations between .01 and .09 are considered negligible, .10 to .29 are low, .30 to .49 are moderate, .50 to .69 are substantial, .70 to .99 are very high, and a correlation of 1.00 is a perfect correlation. Pearson Product Moment correlations were used to determine the relationships between the variables (see Table 4-12).

As would be expected, very high correlation was found between content knowledge posttest score and content knowledge gain score (r = .70). Substantial correlations were discovered between content knowledge posttest score, content knowledge pretest score (*r* = .50), and science process skill posttest (*r* = .55). A substantial correlation was also found between science process skill posttest score and science process skill gain score (r = .65). A moderate correlation was discovered between content knowledge posttest score and science process skill pretest score (*r* = .46). Moderate correlations were also discovered between content knowledge pretest score and science process skill pretest score (*r* = .48) and science process skill posttest score (*r* = .43). Moderate correlations were also discovered between science process skill pretest score and content knowledge posttest (*r* = .44), science process skill posttest score (*r* = .47), science process gain score (*r* = -.36), and GEFT score (*r* = .42). Additionally, moderate correlations were discovered between GEFT score and science process skill posttest score (*r* = .38). Several variables with low correlations were observed.

Table 4-12 Correlations Between Variables

Variable	1	2	3	4	5	6	7
1. Content Pretest	--	.504	-.258	.479	.431	.062	.260
2. Content Posttest		--	.704	.441	.552	.248	.292
3. Content Gain Score			--	.106	.289	.231	.089
4. Science Process Pretest				--	.474	-.356	.420
5. Science Process Posttest					--	.654	.377
6. Science Process Gain Score						--	.031
7. GEFT Score							--

Objective Two: Describe the Variance in Content Knowledge Gain Score Attributed to Learning Styles, Ethnicity, and Other Demographic Characteristics.

To address this objective, backwards-stepwise regression was selected as the means by which to determine the best model for predicting content knowledge gain score. Variables were removed from the model if that variable's *F*-value did not have a probability equal to or less than .05. The backward regression procedure was selected due to the fact that it utilizes all available variables to build a model that consists of only variables that contribute significantly to predicting the dependent variable (Agresti & Finlay, 1997). Variables first included in the backward regression model were ethnicity, gender, learning style, grade level, treatment group, content knowledge pretest, and science process skill pretest.

The following categorical variables were entered using dummy codes:

- Learning Style: 1 = field-dependent; 0 = field-independent
- Gender: 1 = male; 0 = female
- Ethnicity: 1 = white, non-Hispanic; 0 = minority
- Grade Level:
  - 9th grade: 1 = yes; 0 = no
  - 10th grade: 1 = yes; 0 = no
  - 11th grade: 1 = yes; 0 = no
- Treatment Group:
  - Subject matter: 1 = yes; 0 = no
  - Prescriptive laboratory: 1 = yes; 0 = no

A model consisting of content knowledge pretest, science process skill pretest, ethnicity, treatment group, and learning style was identified as being the best model to predict content knowledge gain score, $F(_{190}) = 16.71$, $p < .001$. R^2 for the model was .35; adjusted R^2 was .33. Table 4-13 shows the regression coefficients for this model. Field-dependent learning style ($t = -2.35$, $p = .02$), subject matter treatment group ($t = 2.40$, $p = .02$), prescriptive laboratory treatment group ($t = -3.86$, $p < .001$), ethnicity ($t = 2.27$, $p =$

.02), science process skill pretest score ($t = 5.07, p <.001$), and content knowledge pretest score ($t = -7.77, p <.001$) contributed significantly ($\alpha = .05$) to predicting content knowledge gain score. These variables accounted for 33% of the variance in content knowledge gain scores.

Table 4-13 Backward Regression Analysis to Predict Content Knowledge Gain Scores

Variable	*B*	*SE*	*β*	*t*	*p*
Constant	9.42	2.04		4.62	<.001
Learning Style[a]	-2.25	.96	-.15	-2.35	.02
Treatment Group					
Subject Matter[b]	2.45	1.02	.18	2.34	.02
Prescriptive Laboratory[b]	-3.63	.94	-.29	-3.86	<.001
Ethnicity[c]	2.14	.94	.14	2.27	.02
Science Process Skill Pretest	.41	.08	.35	5.07	<.001
Content Knowledge Pretest	-.67	.09	-.54	-7.77	<.001

Note. $F(_{190}) = 16.71, p <.001$; $R^2 = .35$; Adjusted $R^2 = .33$

[a] Coded as 1 = field-dependent; 0 = field-independent

[b] Coded as 1 = member of group; 0 = not a member of group

[c] Coded as 1 = white, non-Hispanic; 0 = minority

Objective Three: Describe the Variance in Science Process Skill Gain Score Attributed to Learning Styles, Ethnicity, and Other Demographic Characteristics.

A procedure similar to that which was used to address objective two was utilized to address this objective. Backwards-stepwise regression was used to select the best model for predicting science process skill gain score using learning styles, ethnicity, and other demographic characteristics. Variables that were categorical in nature were coded in the same manner as was done in objective two of this study. A model including the variables of learning style, treatment group, gender, science process pretest, and content knowledge pretest was found to be the most predictive. This linear combination of variables significantly predicted science process skill gain scores, $F(_{157}) = 18.39, p <.001$. R^2 for the model was .38, adjusted R^2 was .36. Table 4-14 shows the regression coefficients for this model. Field-dependent learning style ($t = -3.01, p = .003$), prescriptive laboratory group membership (t = -5.30, p <.001), gender (t = -2.52, p = .01), science process skill pretest score (t = -6.51, p <.001), and content knowledge pretest score (t = 2.38, p =.02) contributed significantly (α = .05) to predicting science process skill gain score. These four variables accounted for 36% of the variance in science process skill gain scores.

Table 4-14 Backward Regression Analysis to Predict Science Process Skill Gain Scores

Variable	*B*	*SE*	*β*	*t*	*p*
Constant	11.20	2.34		5.00	<.001
Learning Style[a]	-3.11	1.03	-.21	-3.01	.003
Treatment Group					
Prescriptive Laboratory[b]	-4.42	.83	-.35	-5.30	<.001
Science Process Skill Pretest	-.58	.09	-.49	-6.51	<.001
Content Knowledge Pretest	.22	.09	.18	2.38	.02
Gender[c]	-2.18	.87	-.16	-2.52	.01

Note: $F_{(157)}$ = 18.39, p <.001; R^2 = .38; Adjusted R^2 = .36

[a] Coded as 1 = field-dependent; 0 = field-independent

[b] Coded as 1 = member of group; 0 = not a member of group

[c] Coded as 1 = male; 0 = female

Hypothesis Tests

The dependent variables in this study were content knowledge gain and science process skill gain. Both of these variables were interval data. The independent variables in this study were learning style, grade level, ethnicity, gender, and treatment group. All independent variables were categorical data. Covariates in this study were content knowledge pretest scores and science process skill pretest scores. Covariates were interval in nature.

Tests of Assumptions of Multivariate Analysis of Covariance

The goal of this study was to examine the effect on the dependent variables (content knowledge gain and science process skill gain) by the independent variables (learning style, grade level, ethnicity, gender, and treatment group). Therefore, the multivariate analysis of covariance (MANCOVA) procedure was used to analyze data.

This procedure is appropriate when determining the differences between categorical independent variables on multiple interval dependent variables while statistically controlling for other variables (Stevens, 1992).

For a single dependent variable, the assumptions for proper application of an analysis of variance procedure require that the groups must be random samples from normal populations with the same variance. Since the MANCOVA procedure is similar in nature to the single variable analysis of variance, these assumptions are extended to this procedure as well. The assumptions of the MANCOVA procedure are the dependent variables have a multivariate normal distribution with an equal variance-covariance matrix in each group (Kirk, 1982). Furthermore, since covariate measures were used, the assumption of homogeneity of regression for the covariate measures must also be met.

Normality

As a quasi-experimental design using intact groups, random sampling of subjects was not possible. Therefore, experimental control of this assumption was not practical, and a possible violation of the normality assumption occurred. However, as suggested by Kirk (1982), some degree of randomization was accomplished through the random assignment of treatment to the intact groups, minimizing this threat.

Homoscedasticity

Homoscedasticity, or homogeneity of variance, was assessed by using Box's M procedure. This statistic follows the F distribution. A statistically significant F value indicates that the homoscedasticity assumption is not met. The Box's M statistic for this study was 76.63, with a value of $F_{(48, 2030)} = 1.18$, $p = .19$. Since the Box's M test statistic was not significant ($\alpha = .05$), the assumption of homoscedasticity was met.

Multivariate Test of Effects

A multiple analysis of covariance procedure was used to determine if significant differences existed between groups of students of different learning styles, grade levels, ethnicity, or gender, and taught using the subject matter, prescriptive laboratory, or investigative laboratory approach. This procedure allows for simultaneous testing of treatment effects on multiple dependent variables while adjusting group means to compensate for sources of variation that could not be controlled in the experiment, but which are believed to affect the dependent variables. Utilizing the MANCOVA procedure reduces experimental error, results in increased power, and reduces experimental bias caused by between-group differences which are attributed to the independent variables (Kirk, 1982).

To simultaneously test the hypothesis that several population means do not differ from a specified set of constants the Hotelling's Trace statistic is used. In this study a Hotelling's Trace statistic was calculated for the effects of the treatment, effects of the learning style, grade level, ethnicity, and gender; and interaction effects of those variables on the dependent variables.

Effect of Treatment

The Hotelling's Trace statistic for the effects of the teaching approach or treatment on the dependent variables was .12, $F_{(4, 154)} = 2.34$, $p = .05$. Table 4-15 contains the data derived from the univariate analysis of effects of the treatment. Since this statistic was significant at the .05 level, a follow-up univariate analysis of covariance was conducted. This follow-up analysis indicated significant differences ($p<.001$) in the content knowledge gain score of students. This follow-up analysis found that students in the subject matter only and investigative laboratory groups had significantly higher content knowledge gain than did students in the prescriptive laboratory group (see Table 4-16).

Table 4-15 Univariate Analysis of Treatment Effects

Source	*df*	*F*	*p*
Content Knowledge Gain Score	2	17.45	<.001
Science Process Skill Gain Score	2	18.65	<.001

Note. Hotelling's T = .12, $F_{(4,\ 154)} = 2.34$, $p = .05$

Table 4-16 Content Knowledge Gain Score Pairwise Comparisons

Group	Group	*M* Difference	*SE*	*p*
SM	PL	5.60	1.04	<.001
SM	IL	1.64	1.14	.15
PL	IL	-3.97	.95	<.001

Significant differences (p <.001) were also discovered in the science process skill gain score of students. Similar to the findings of the content knowledge gain, students in the subject matter only and investigative laboratory groups had significantly higher science process gain scores than did students in the prescriptive laboratory group (see Table 4-17).

Table 4-17 Science Process Skill Gain Score Pairwise Comparisons

Group	Group	*M* Difference	*SE*	*p*
SM	PL	5.84	1.02	<.001
SM	IL	1.66	1.30	.20
PL	IL	-4.18	1.14	<.001

Effects of Learning Style

The Hotelling's Trace statistic for the effects of learning style on the dependent variables was .18, $F_{(4,\ 154)} = 3.37$, $p = .01$. Since this statistic was significant at the .05 level, a follow-up univariate analysis of covariance was conducted. This follow-up analysis indicated no significant differences ($p = .24$) in the content knowledge gain score of students. Furthermore, no significant differences ($p = .18$) were discovered in the science process skill gain score of students. Table 4-18 contains data derived from the univariate analysis of effects of the treatment.

Table 4-18 Univariate Analysis of Learning Style Effects

Source	*df*	*F*	*p*
Content Knowledge Gain Score	2	1.458	.236
Science Process Skill Gain Score	2	1.766	.175

Note. Hotelling's T = .18, $F_{(4, 154)} = 3.37$, $p = .01$

Effects of Demographic Variables

No demographic variable had a Hotelling's Trace statistic that was significant at the .05 level. Table 4-19 contains the multivariate analysis data. Since no variable was found to significantly contribute to either dependent variable (content knowledge gain score or science process skill gain score), further univariate analysis was not needed.

Table 4-19 Multivariate Analysis of Demographic Variable Effects

Source	Hotelling's Trace	*F*	*p*
Grade Level	.102	1.306	.258
Ethnicity	.103	1.316	.253
Gender	.022	.868	.424

Effects of Interaction of Variables

No interaction of variables analysis yielded a Hotelling's Trace statistic that was significant at the .05 level. Since no interaction was found to significantly contribute to either dependent variable (content knowledge gain score or science process skill gain score), further univariate analysis was not needed.

Test of Hypotheses

To determine if significant differences existed in the content knowledge gain score and science process skill gain score of students taught in classes using the subject matter, prescriptive laboratory, or investigative laboratory approaches, and to determine the effect of student learning styles on those differences, hypotheses were formulated to guide this study. The decisions to retain or reject the null hypotheses were based upon the findings of the multivariate analysis of covariance and subsequent univariate analysis of covariance procedures used to analyze the data. Results of the test of hypotheses are presented as they pertain to student content knowledge gain and science process skill gain.

Hypotheses Related to Content Knowledge Gain

HO$_1$: There is no difference in the content knowledge gain scores of agricultural education students taught using the subject matter, prescriptive laboratory, or investigative laboratory approach.

Student content knowledge gain score was calculated by subtracting the student's content knowledge pretest score from his or her content knowledge posttest score. Table 4-20 contains the summary statistics of gain scores by treatment.

Table 4-20 Mean Gain Scores by Treatment

Gain Score	SM	PL	IL
Content Knowledge	6.27	1.71	5.04
Science Process Skill	2.02	-2.50	3.21

Students taught using the subject matter approach recorded the highest mean content knowledge gain score (*M* = 6.27). The univariate analysis of covariance revealed significant differences in content knowledge gain score at the alpha level of .05 for content knowledge gain scores between students taught by the three approaches. Based upon these findings, the null hypothesis of no difference in content knowledge gain scores of students taught by using the subject matter, prescriptive laboratory, or investigative laboratory approaches was rejected.

HO$_2$: There is no difference in the content knowledge gain scores of agricultural education students of different learning styles.

Field-Independent learners recorded the highest mean content knowledge gain score (*M* = 4.80). The univariate analysis of covariance failed to reveal significant differences in content knowledge gain score at the alpha level of .05 for content knowledge gain scores between students of various learning styles. Based upon these findings, the null hypothesis of no difference in content knowledge gain scores of students of various learning styles failed to be rejected. Table 4-21 contains the summary statistics of gain scores by learning style.

Table 4-21 Mean Gain Scores by Learning Style

Gain Score	FD	FN	FI
Content Knowledge	3.45	3.61	4.80
Science Process Skill	-.56	-.44	.77

HO$_3$: There is no difference in the content knowledge gain scores of agricultural education students of different learning styles taught using the subject matter, prescriptive laboratory, or investigative laboratory approach.

Field-Neutral learners taught using the subject matter approach recorded the highest mean content knowledge gain score (*M* = 7.50). However, the multivariate analysis of covariance failed to reveal significant differences in content knowledge gain score at the alpha level of .05 for content knowledge gain scores between students taught by the three approaches across learning styles. Therefore, the null hypothesis of no difference in content knowledge gain scores of students of various learning styles taught by using the subject matter, prescriptive laboratory, or investigative laboratory approaches failed to be rejected. Table 4-22 contains the summary statistics of gain scores by treatment across learning styles.

Table 4-22 Mean Content Knowledge Gain Scores by Treatment Across Learning Styles

	SM	PL	IL
Field-Dependent	5.82	1.58	4.00
Field-Neutral	7.50	.57	4.14
Field-Independent	6.50	2.01	6.78

Hypotheses Related to Science Process Skill Gain

HO$_4$: There is no difference in the science process skill gain scores of agricultural education students taught using the subject matter, prescriptive laboratory, or investigative laboratory approach.

Students taught using the investigative laboratory approach recorded the highest mean science process skill gain score (*M* = 3.21). The univariate analysis of covariance revealed significant differences in science process skill gain score at the alpha level of .05 for science process skill gain scores between students taught by the three approaches. Based upon these findings, the null hypothesis of no difference in science process skill gain scores of students taught by using the subject matter, prescriptive laboratory, or investigative laboratory approaches was rejected. Table 4-20 contains the summary statistics of gain scores by treatment.

HO$_5$: There is no difference in the science process skill gain scores of agricultural education students of different learning styles.

Field-Independent learners recorded the highest mean science process skill gain score (*M* = .77). However, a univariate analysis of covariance failed to reveal significant differences in science process skill gain score at the alpha level of .05 for science process skill gain scores between students of various learning styles. Based upon these findings, the null hypothesis of no difference in science process skill gain scores of students of various learning styles failed to be rejected. Table 4-21 contains the summary statistics of gain scores by learning style.

HO$_6$: There is no difference in the science process skill gain scores of agricultural education students of different learning styles taught using the subject matter, prescriptive laboratory, or investigative laboratory approach.

Field-Independent learners taught using the investigative laboratory approach recorded the highest mean science process skill gain score (*M* = 4.40). However, a multivariate analysis of covariance failed to reveal significant differences in science process skill gain score at the alpha level of .05 for science process skill gain scores between students taught by the three approaches across learning styles. Therefore, the null hypothesis of no difference in science process skill gain scores of students of various learning styles taught by using the subject matter, prescriptive laboratory, or investigative laboratory approaches failed to be rejected. Table 4-23 contains the summary statistics of gain scores by treatment across learning styles.

Table 4-23 Mean Science Process Skill Gain Scores by Treatment Across Learning Styles

	SM	PL	IL
Field-Dependent	1.07	-2.72	2.83
Field-Neutral	3.50	-4.17	.60
Field-Independent	3.25	-1.08	4.40

Summary

This chapter presented the findings of this study. The findings were organized around the objectives and hypothesis that guided this research. The objectives were: (1) describe the learning styles, ethnicity, and other demographic characteristics of participants in this study; (2) describe the variance in content knowledge gain score attributed to learning styles, ethnicity, and other demographic characteristics; and (3) describe the variance in science process skill gain score attributed to learning styles, ethnicity, and other demographic characteristics. The null hypotheses tested in this study were: (1) there is no difference in the content knowledge gain scores of agricultural education students taught using the subject matter, prescriptive laboratory, or investigative laboratory approach; (2) there is no difference in the content knowledge gain scores of agricultural education students of different learning styles; (3) There is no difference in the content knowledge gain scores of agricultural education students of different learning styles taught using the subject matter, prescriptive laboratory, or investigative laboratory approach; (4) there is no difference in the science process skill gain scores of agricultural education students taught using the subject matter, prescriptive laboratory, or investigative laboratory approach; (5) there is no difference in the science process skill gain scores of agricultural education students of different learning styles; (6) there is no difference in the science process skill gain scores of agricultural education students of different learning styles taught using the subject matter, prescriptive laboratory, or investigative laboratory approach.

The findings presented in this chapter will be discussed in greater detail in Chapter 5. Additionally, conclusions, recommendations, and implications regarding these findings will also be presented.

CHAPTER 5
SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The purpose of this study was to determine the effect of investigative laboratory integration on student content knowledge achievement and science process skill achievement across learning styles, gender, and ethnicity. The independent variable in this study was the teaching method used in selected agricultural education classes. The treatment groups utilized one of three levels of treatment: subject matter approach without laboratory experimentation, subject matter approach with prescriptive laboratory experimentation, and subject matter approach with investigative laboratory experimentation. Characteristics that were treated as antecedent variables were student learning style, ethnicity, and gender. Covariates were used to adjust group means in order to compensate for previous knowledge of the subject matter. These covariate measures included pretests for the unit of instruction. The following research objectives and hypotheses guided this study.

Objectives

1. Describe the learning styles, ethnicity, and other demographic characteristics of participants in this study.
2. Describe the variance in content knowledge gain score attributed to learning styles, ethnicity, and other demographic characteristics.
3. Describe the variance in science process skill gain score attributed to learning styles, ethnicity, and other demographic characteristics.

Null Hypotheses

All statistical analyses that involved significance testing were tested at an alpha level of .05. This equates to a five percent chance of a Type I error. A Type I error occurs if significance was determined when in fact there was none.

- HO_1: There is no difference in content knowledge gain scores of agricultural education students taught using the subject matter, prescriptive laboratory, or investigative laboratory approach.
- HO_2: There is no difference in content knowledge gain scores of agricultural education students of different learning styles.
- HO_3: There is no difference in content knowledge gain scores of agricultural education students of different learning styles taught using the subject matter, prescriptive laboratory, or investigative laboratory approach.
- HO_4: There is no difference in science process skill gain scores of agricultural education students taught using the subject matter, prescriptive laboratory, or investigative laboratory approach.
- HO_5: There is no difference in science process skill gain scores of agricultural education students of different learning styles.
- HO_6: There is no difference in science process skill gain scores of agricultural education students of different learning styles taught using the subject matter, prescriptive laboratory, or investigative laboratory approach.

Methods

This study was conducted using a quasi-experimental design referred to by Campbell and Stanley (1963) as the nonequivalent control group design. The independent variable in this study was the teaching method used in an introductory agriscience course. The dependent variables were student content knowledge achievement and science process skill achievement. Antecedent variables were student learning style, ethnicity, and gender. Student content knowledge pretest score, and science process skill pretest score were used as covariate measures.

The population for this study was Florida students enrolled in an introductory agriscience course. A purposively selected sample based upon the ability of the teacher to effectively deliver all three teaching approach treatments was selected from the population. After being selected for the study, each teacher was assigned one of the three treatments.

Following the suggestion made by Boone (1988) for conducting teaching method studies using teachers to deliver the treatment, precautions were taken to ensure teacher conformity to the assigned teaching approach. Professional development in the form of personal instruction and a videotape containing instructions and a lesson demonstration was provided for each teacher in the study. All materials needed by the teacher to deliver the treatment (lesson plans, handouts, assessment instruments, etc.) were provided by the researcher. Furthermore, the teachers audio recorded each lesson in which the treatment was delivered. These audio tapes were then analyzed to determine the level to which the treatment was delivered. Students in classes in which the assigned teaching approach had not been properly utilized were removed from the study.

The researcher developed instructional plans appropriate to the teaching methods used in each level of the treatment. The content of the unit was designed to address Florida Student Performance Standard 06.0 for the Agriscience Foundations I course (Florida Department of Education, 2002), specifically plant germination and plant functions. The subject matter to be taught was consistent among all three sets of instructional plans. The instructional plans were evaluated for content validity by a panel of experts from the Agricultural Education and Communication Department at the University of Florida.

Instruments to collect data for the variable of content knowledge achievement were developed by the researcher. This instrument was determined to be a valid and reliable instrument through review by an expert panel and the calculation of a post-hoc reliability coefficient of .92 using the Kuder-Richarson 20 formula. Parallel forms of this instrument were used prior to (pretest) and immediately following (posttest) the administration of the treatment.

The Test of Integrated Process Skill (TIPS), developed by Dillashaw and Okey (1980), was used to assess the science process skill ability of students. Parallel forms of this instrument were used to collect both pretest and posttest data. This instrument was found to have a post-hoc reliability coefficient of .72 using the Kuder-Richarson 20 formula.

The Group Embedded Figures Test (Witkin et al., 1971) was used to measure the student learning style. Data concerning the variables of student ethnicity, gender, and other demographic information were reported to the research by the school's student services department from student records.

Data were analyzed using the SPSS® version 12.0 for Windows® software package. Analysis of the first objective involved descriptive statistics and included frequencies, means, and standard deviations. The next two objectives were examined using backward regression analyses. All hypotheses were tested using multivariate analysis of covariance (MANCOVA). Univariate analysis of covariance (ANCOVA) was used as a follow-up procedure, when appropriate.

Summary of Findings

The findings of this study are summarized using the objectives and hypotheses presented in earlier chapters.

Objective One

The first objective sought to describe the purposively selected sample of this study. A majority (62.7%) of the students involved in this study were in the ninth grade. The second largest grade level represented was the tenth grade (19.9%). The remainder of the sample was in the eleventh grade (12.1%) and the twelfth grade (5.3%). Variations in the demographic make-up of each of the treatment groups were noted. All results should be interpreted with that caution in mind.

The majority (66.5%) of students in the study were male. A majority (56.0%) of the students selected “White, non-Hispanic” as their ethnic group. The next largest group of participants was Hispanic (34.5%), followed by Black (7.9%) and Other (1.6%). Variations in the ethnic composition of each of the treatment groups were noted. All results should be interpreted with that caution in mind.

The mean Group Embedded Figures Test (GEFT) score for respondents of this study was 7.6 (*SD* = 4.74). A majority (60.7%) of students were categorized as field-dependent in their learning style. Field-independent learners constituted the second largest group (23.2%) followed by field-neutral learners (16.1%). Variations in the learning style composition of each of the treatment groups were noted. All results should be interpreted with that caution in mind.

Student content knowledge achievement was determined using the researcher developed content knowledge achievement pretest and posttest instruments. The maximum possible score on these parallel instruments was 50. The pretest mean was 16.39 (*SD* = 5.04) across all students. A posttest mean of 20.59 (*SD* = 6.79) was reported across all respondents. The mean content knowledge gain score was 3.93 (*SD* = 6.15).

These means are extremely low. The posttest mean indicated that on average students only answered approximately 41% correctly.

The Test of Integrated Process Skills was used to determine the science process skill level of students. This instrument is considered a standardized test and was developed by Dillashaw and Okey (1980). Parallel versions of this instrument were given to the students at two collection points in the study (pretest and posttest). The maximum score of this instrument is 36. The pretest mean was 15.57 (*SD* = 5.66) across all students. A posttest mean of 15.81 (*SD* = 6.66) was reported across all respondents. The mean content knowledge gain score was -0.17 (*SD* = 6.33). These means are extremely low. The posttest mean indicated that on average students only answered approximately 44% correctly.

The relationships between the variables discussed above were also examined. A very high correlation was found between content knowledge posstest score and content knowledge gain score (r = .70). Substantial correlations were discovered between content knowledge posttest score, content knowledge pretest score (r = .50), and science process skill posttest (*r* = .55). A substantial correlation was also found between science process skill posttest score and science process skill gain score (*r*= .65). A moderate correlation was discovered between content knowledge posttest score and science process skill pretest score (*r* = .46). Moderate correlations were also discovered between content knowledge pretest score and science process skill pretest score (*r* = .48) and science process skill posttest score (*r* = .43). Moderate correlations were also discovered between science process skill pretest score and content knowledge posttest (*r* = .44), science process skill posttest score (*r* = .47), science process gain score (*r* = -.36), academic performance rating (*r* = .41), and GEFT score (*r* = .42). Additionally, moderate correlations were discovered between GEFT score and science process skill posttest score (*r* = .38) and academic performance rating (*r* = .32). Several variables with low correlations were observed.

Objective Two

This objective sought to describe the variance in content knowledge gain score attributed to leaning styles, ethnicity, and other demographic characteristics. The backward regression procedure was selected to address this objective. A model consisting of field-dependent learning style (*t* = -2.35, *p* = .02), subject matter treatment group (*t* = 2.40, *p* = .02), prescriptive laboratory treatment group (*t* = -3.86, *p* <.001), ethnicity (*t* = 2.27, *p* = .02), science process skill pretest score (*t* = 5.07, *p* <.001), and content knowledge pretest score (*t* = -7.77, *p* <.001) was identified that accounted for 33% of the variance in content knowledge gain score.

Objective Three

This objective sought to describe the variance in science process skill gain score attributed to leaning styles, ethnicity, and other demographic characteristics. The backward regression procedure was selected to address this objective. A model consisting of field-dependent learning style (*t* = -3.01, *p* = .003), prescriptive laboratory group membership (*t* = -5.30, *p* <.001), gender (*t* = -2.52, *p* = .01), science process skill pretest score (*t* = -6.51, *p* <.001), and content knowledge pretest score (*t* = 2.38, *p* =.02) was identified that accounted for 36% of the variance in science process skill gain score.

Null Hypothesis One

The first null hypothesis for this study was that there is no difference in the content knowledge gain scores of agricultural education students taught using the subject matter, prescriptive laboratory, or investigative laboratory approach. The MANCOVA procedure was used to test this hypothesis. The Hotelling's Trace statistic for group effects on the dependent variables was .12, $F_{(4,\ 154)} = 2.34$, p = ..05. The effect size was .06 and the power was .67. The follow up univariate analysis of covariance revealed significant differences in content knowledge gain score between students in the various treatment groups. Therefore the null hypothesis was rejected.

Null Hypothesis Two

The second null hypothesis for this study was that there is no difference in the content knowledge gain scores of agricultural education students of various learning styles. The MANCOVA procedure was used to test this hypothesis. The Hotelling's Trace statistic for learning style effects on the dependent variables was .18, $F_{(4,\ 154)} = 3.37$, $p = .01$. The effect size was .08 and the power was .84. The follow up univariate analysis of covariance failed to reveal significant differences in content knowledge gain score between students of various learning styles. Therefore the null hypothesis was not rejected.

Null Hypothesis Three

The third null hypothesis for this study was that there is no difference in the content knowledge gain scores of agricultural education students of various learning styles taught using the subject matter, prescriptive laboratory, or investigative laboratory approach. The MANCOVA procedure was used to test this hypothesis. The Hotelling's Trace statistic for group effects on the dependent variables was .07, $F_{(8,\ 154)} = .65$, $p = .73$. The effect size was .03 and the power was .29. This multivariate analysis of covariance failed to reveal significant differences in content knowledge gain score between students in the various treatment groups across learning styles. Therefore, the null hypothesis failed to be rejected.

Null Hypothesis Four

The fourth null hypothesis for this study was that there is no difference in the science process skill gain scores of agricultural education students taught using the subject matter, prescriptive laboratory, or investigative laboratory approach. The MANCOVA procedure was used to test this hypothesis. The Hotelling's Trace statistic for group effects on the dependent variables was .12, $F_{(4,\ 154)} = 2.34$, $p = .05$. The effect size was .06 and the power was .67. The follow up univariate analysis of covariance revealed significant differences in science process gain score between students in the various treatment groups. Therefore, the null hypothesis was rejected.

Null Hypothesis Five

The fifth null hypothesis for this study was that there is no difference in the science process skill gain scores of agricultural education students of different learning styles. The MANCOVA procedure was used to test this hypothesis. The Hotelling's Trace statistic for learning style effects on the dependent variables was .18, $F_{(4,\ 154)} = 3.37$, $p = .01$. The effect size was .08 and the power was .84. The follow up univariate analysis of covariance failed to reveal significant differences in science process skill gain score between students of various learning styles. Therefore, the null hypothesis was not rejected.

Null Hypothesis Six

The sixth and final null hypothesis for this study was that there is no difference in the science process skill gain scores of agricultural education students of different learning styles taught using the subject matter, prescriptive laboratory, or investigative laboratory approach. The MANCOVA procedure was used to test this hypothesis. The Hotelling's Trace statistic for group effects on the dependent variables was .07, $F_{(8,\ 154)} = .65$, $p = .73$. The effect size was .03 and the power was .29. This multivariate analysis of covariance failed to reveal significant differences in science process skill gain score between students in the various treatment groups across learning styles. Therefore, the null hypothesis failed to be rejected.

Conclusions

The sample used in this study was not randomly drawn from the population. With this limitation in mind, and based on the findings of this study, the following conclusions were drawn.

1. Participants in this study were predominantly White (56.0%), male (66.5%), and enrolled in the ninth grade (62.7%). Hispanics comprised 34.5% of the participants. The majority of students were field-dependent in their learning style (60.7%).

2. Of the students who participated in this study, white, non-Hispanic students with a field-independent learning style taught using the subject matter approach with higher science process skill pretest scores and lower content knowledge pretest scores tended to have higher content knowledge gain scores.

3. Of the students who participated in this study, female students with a field-independent learning style taught using the subject matter or investigative laboratory approach with lower science process skill pretest scores and higher content knowledge pretest scores tended to have higher science process gain scores.

4. When taught using the subject matter, prescriptive laboratory, or investigative laboratory approaches, students taught using the subject matter approach or the investigative laboratory approach to teaching tended to have the higher content knowledge gain scores as compared to students taught using the prescriptive laboratory approach.

5. When taught using the subject matter, prescriptive laboratory, or investigative laboratory approaches, students of varying learning styles had similar content knowledge gain scores.

6. When taught using the subject matter, prescriptive laboratory, or investigative laboratory approaches, students of varying learning styles had similar content knowledge gain scores regardless of teaching method used.

7. When taught using the subject matter, prescriptive laboratory, or investigative laboratory approaches, students taught using the subject matter approach or the investigative laboratory approach to teaching tended to have higher science process skill gain scores, as compared to students taught using the prescriptive laboratory approach.
8. When taught using the subject matter, prescriptive laboratory, or investigative laboratory approaches, students of varying learning styles had similar science process skill gain scores.
9. When taught using the subject matter, prescriptive laboratory, or investigative laboratory approaches, students of varying learning styles had similar science process skill gain scores regardless of teaching method used.

Discussion and Implications

Objective One: Describe the Learning Style, Ethnicity, and Other Demographic Characteristics of Participants in This Study.

Conclusion: Participants in this study tended to be White males in the ninth grade. They tended to be field-dependent in their learning style

It was expected that the majority of participants in this study would be in the ninth grade. Since the population for this study was students enrolled in the Agriscience Foundations I course in Florida high school agricultural education programs. As the name implies, this course was an introductory course in agricultural education, and as such, is the first agricultural education course in which students enroll upon entering high school. The finding that approximately 17% of the students in the study were upperclassmen (eleventh and twelfth graders) was somewhat surprising due to the introductory nature of the course. However, since this course counts as a science credit toward graduation, these upperclassmen may be enrolling in this course for that reason. If so, this might indicate that upperclassmen taking Agriscience Foundations I are not in a college preparatory curriculum, since those students would likely have completed their introductory science requirements by this time. Another possible explanation may be that these students are only looking for what they perceive to be a less difficult science credit course. Other possible explanations could be that due to more strict graduation requirement or possibly school overcrowding, these upperclassmen were not able to enroll in this introductory course at an earlier date. Further research is needed to understand the motivation of students enrolling in this type of agricultural education course.

The finding that most students in this study were field-dependent in their learning style was not surprising due to previous learning style research with students of similar ages. This finding concurred with Cox, Sproles, and Sproles' (1988) finding that students 14-15 years of age possess a learning style with characteristics similar to those identified in this study as of field-dependent learners. The finding that older students in the study were also field-dependent differs from findings of earlier studies concerning learning styles at the high school level (Dyer, 1995; Howard & Yoder, 1987; Witkin et al., 1977). However, Cox et al. opined that student learning style becomes more concrete as the number of agricultural education courses enrolled in increase (e.g., they become more concrete in learning style as they get older). Since this is most likely the first agricultural education course for these older students, this may explain why the older students exhibited a more field-dependent (abstract) learning style. However, further research in this area is warranted.

A substantial correlation ($r = .50$) was found between student content knowledge pretest and posttest scores, indicating that students who had a higher level of content knowledge entering the study were able to achieve higher scores on the posttest. This may indicate the presence of a predisposition to learn science-related materials. Further investigation in this area is needed to better understand this phenomenon.

The finding that most students in the study categorized their ethnicity as White is not surprising. The majority of students enrolled in public schools in the state of Florida are also categorized as White (Florida Department of Education, 2003). Hispanics were the second most represented ethnic group in this study followed by Blacks. This differs slightly from the state enrollment totals. The number of individuals identifying themselves as Black was the second largest ethnic group with Hispanics being third. Research is needed to determine why black students are not enrolling in agricultural education courses at the high school level.

Overall, the posttest scores for all students involved in the study were very low. Further investigation is needed to address why students achieved so poorly. It is of concern when a great deal of time is spent in teaching a unit of instruction and the result is a small amount of knowledge gain.

Objective Two: Describe the Variance in Content Knowledge Gain Score Attributed to Learning Styles, Ethnicity, and Other Demographic Characteristics.

Conclusion: Of the students who participated in this study, white, non-Hispanic students with a field-independent learning style taught using the subject matter approach with higher science process skill pretest scores and lower content knowledge pretest scores tended to have higher content knowledge gain scores.

The finding that students with less prior knowledge in the content area had higher content knowledge gain scores at the conclusion of instruction is contradictory to the findings of Roberts (2003). However, students with greater science process skill achievement prior to instruction showed higher content knowledge gain. Likewise, student science process skill pretest score was moderately correlated (r = .44) with content knowledge posttest score.

Gender did not contribute significantly to explaining the variance in content knowledge achievement. However, learning style was found to play a role in knowledge gain. Students with a field-independent learning style were predicted to have more than double (2.25) the content knowledge gain as compared to field-dependent learners when all other variables are controlled. Previous research regarding the influence of learning styles on achievement was inconclusive. These findings, however, are inconsistent with the studies that reported no difference in gain scores based on learning styles (Day, Raven, & Newman, 1998; Freeman, 1995; Roberts, 2003; Shih & Gamon, 2001).

The regression equation predicted that white, non-Hispanic students would have gain scores 2.14 times greater than that of minority students when all other variables are held constant. Further research is needed to better understand the cause of this gain discrepancy. Of particular interest is the effect of socioeconomic status of students on achievement. Are ethnicity and socioeconomic status coterminous as Abbot and Joirman (2001) suggest? If that is the case, what can educators do to mitigate the effect?

Objective Three: Describe the Variance in Science Process Skill Gain Score Attributed to Learning Styles, Ethnicity, and Other Demographic Characteristics.

Conclusion: Of the students who participated in this study, female students with a field-independent learning style taught using the subject matter or investigative laboratory approach with lower science process skill pretest scores and higher content knowledge pretest scores tended to have higher science process gain scores.

Field-independent learners tend to more easily be able to organize materials and solve problems (Dyer, 1995). Dyer further noted that this type of learner favors more scientific areas such as mathematics, physics, chemistry, and biology. Furthermore, Dyer opined that these learners may perform better when allowed to develop their own strategies to address an issue. With these characteristics in mind, it is not surprising that field-independent learners would tend to have higher science process skill achievement. A review of the objectives of the Test of Integrated Process Skills (Dillashaw and Okey, 1980) reveals that many of these traits lead to greater science process skill ability. This may indicate a predisposition of some individuals to learn science-related material. Further research is needed to investigate the possible presence of this predisposition.

Similar to the finding in objective two, students with lower initial levels of science process skill were found to have higher science process gain scores. This may be due to the fact that these students had more room to grow in this area, compared to their counterparts who entered the treatment with higher levels of science process skill.

It is intriguing to note that the regression equation predicts that female students are likely to attain 2.18 times the science process gain scores as compared to males, when all other variables are held constant. This contradicts the often commonly held notion that females students under-perform their male counterparts in the area of science. However, it should be noted that agriculture often attracts females who tend to be field-independent in their learning style and therefore does not represent a normal distribution. Further research should be conducted to explain this large difference in gain between the genders.

Hypotheses Related to Content Knowledge Gain

Null Hypothesis One: There is no difference in the content knowledge gain score of agricultural education students taught using the subject matter, prescriptive laboratory, or investigative laboratory approach.

Conclusion: When taught using the subject matter, prescriptive laboratory, or investigative laboratory approaches, students taught using the subject matter approach or the investigative laboratory approach to teaching tended to have the higher content knowledge gain scores as compared to students taught using the prescriptive laboratory approach

Null Hypothesis Two: There is no difference in the content knowledge gain score of agricultural education students of various learning styles.

Conclusion: When taught using the subject matter, prescriptive laboratory, or investigative laboratory approaches, students of varying learning styles had similar content knowledge gain scores.

Null Hypothesis Three: There is no difference in the content knowledge gain score of agricultural education students of various learning styles taught using the subject matter, prescriptive laboratory, or investigative laboratory approach.

Conclusion: When taught using the subject matter, prescriptive laboratory, or investigative laboratory approaches, students of varying learning styles had similar content knowledge gain scores regardless of teaching method used.

The findings of this study suggest that students taught using either the subject matter approach or investigative laboratory approach to teaching had higher content knowledge gain scores than students taught using the prescriptive laboratory treatment level. This finding did not support the research conducted by Osborne (2000) involving similar secondary students. Osborne reported that students who participated in prescriptive laboratory activities developed higher levels of content knowledge achievement than those using investigative laboratories. Therefore, a decision must be made by the practicing teacher of which approach to employ in their classroom.

Whereas it was reported by the teachers involved in this study that the investigative approach took a substantially longer period of time to implement than did the subject matter approach (1900 minutes, as compared to 1410 minutes, respectively), it would follow that most teachers would select the shorter time frame. However, upon investigation as to the level of cognitive ability at which content knowledge was assessed, the vast majority of questions on the assessment instruments addressed only the lower levels of Bloom's Taxonomy (Anderson & Krathwohl, 2001). While this is similar in nature to the questions found on many of the standardized test instruments that are common in today's educational environment, the question remains as to how these teaching approaches affect student understanding at the higher levels of Bloom's

Taxonomy. Further research is needed to assess this question. Whereas it is understood that knowledge at the lower levels is needed to form a strong foundation upon which to build, it is equally important to address knowledge and understanding at the higher levels.

Learning styles of students were not found to have significant influence on content knowledge gain score, either alone or in interaction with level of treatment (teaching method). This finding concurred with the research conducted by Garton, Spain, Lamberson, and Spiers (1999) involving secondary students. However, Dyer and Osborne (1996a) reported finding differences in student achievement based on learning style. This study adds another dimension to the investigation of the effect of learning style on content knowledge achievement.

The mean Group Embedded Figures Test (GEFT) score was 7.6 (*SD* = 4.74). This indicates that, in general, students in this study were strongly field-dependent. The national grand mean of this learning style instrument, as reported by its authors (Witkin et al., 1971), was 11.3. Although no statistical significance was found across learning styles, further investigation into the influence of learning styles at the extremes of the scale may be warranted.

Anecdotally, it was apparent that teachers in this study had not used the investigative approach before since they were not familiar with investigative or inquiry based teaching approaches. Therefore it is likely that the Hawthorne effect was a concern. The novelty of this new teaching method may have influenced the effectiveness of the treatment. It was noted that participating teachers that were assigned to the subject matter or prescriptive laboratory groups were much more familiar, and therefore more comfortable, with the teaching method. The lack of familiarity and teaching confidence in teachers assigned the investigative laboratory grouping may have had a negative effect on student gain scores in both content knowledge and science process skill. All findings of this study should be interpreted with this concern in mind.

Although the difference in content knowledge gain score between levels of treatment was found to be statistically significant, further analysis showed that this finding had an effect size of only .06 and a power of .67. This means that the effect of the treatment resulted in a .06 standard deviation increase in content knowledge gain. Using the classification taxonomy suggested by Cohen (1988) for effect size, this is considered a small effect.

Hypotheses Related to Science Process Skill Gain

Null Hypothesis Four: There is no difference in the science process skill gain score of agricultural education students taught using the subject matter, prescriptive laboratory, or investigative laboratory approach.

Conclusion: When taught using the subject matter, prescriptive laboratory, or investigative laboratory approaches, students taught using the subject matter approach or the investigative laboratory approach to teaching tended to have the higher levels of science process skill gain scores as compared to students taught using the prescriptive laboratory approach

Null Hypothesis Five: There is no difference in the science process skill gain score of agricultural education students of various learning styles.

Conclusion: When taught using the subject matter, prescriptive laboratory, or investigative laboratory approaches, students of varying learning styles had similar science process skill gain scores.

Null Hypothesis Six: There is no difference in the science process skill gain score of agricultural education students of various learning styles taught using the subject matter, prescriptive laboratory, or investigative laboratory approach.

Conclusion: When taught using the subject matter, prescriptive laboratory, or investigative laboratory approaches, students of varying learning styles had similar science process skill gain scores regardless of teaching method used.

The findings of this study suggest that students taught using the investigative laboratory approach or the subject matter approach to teaching had higher science process skill gain scores than students taught using the prescriptive laboratory treatment level. This finding did not support the research conducted by Osborne (2000) involving similar secondary students. Osborne reported that students who participated in prescriptive laboratory activities developed higher levels of science process skill than those using investigative laboratories. Furthermore, Germann (1989) reported no significant difference in the science process skill ability of ninth and tenth grade students who were taught using techniques similar to those used in the investigative laboratory group when compared to traditional teaching methods. In light of these conflicting findings, further research into the effect of teaching method on student science process skill development is warranted.

Learning style of the student was not found to have significant influence on science process skill gain score either alone or in interaction with level of treatment (teaching method). However, GEFT score was found to be moderately correlated with both science process skill pretest (r = .42) and science process skill posttest (r = .38). As stated earlier, the mean Group Embedded Figures Test (GEFT) score was 7.6 (*SD* = 4.74). This indicates that, in general, this group was strongly field-dependent. Dyer (1995) stated that field-dependent learners tend to work better in situations where structure is provided for them, such as in the subject mater and prescriptive laboratory methods. Field-independent learners on the other hand tend to prefer a hypothesis-testing approach to learning and are better able to provide their own structure in learning activities such as in the investigative laboratory approach. Therefore, it stands to reason that field-independent learners would enjoy and perhaps experience more success in classrooms in which the investigative approach was utilized. Further investigation into this phenomenon is suggested.

As was the case with content knowledge gain, the difference in science process skill gain scores between levels of treatment was found to be have an effect size of .06 and a power of .67, which is considered a small effect (Cohen ,1988).

Recommendations for Practitioners

Based on the findings of this study, the following recommendations were made for practitioners in secondary agricultural education:

1. A combination of teaching methods should be used to assist students in increasing both content knowledge and science process skill. Whereas different teaching methods were identified as being the most effective in these two areas, they should likely be used in combination. Although the individual differences in student learning style were present, no one teaching method produced a high level of achievement of gain across all groups.

2. Whereas students of varying learning styles recorded similar levels of achievement in both content knowledge and science process skill, teachers may utilize these teaching methods in their classrooms to address all learning styles.

3. Anecdotally, it was found that teachers were not familiar with investigative or inquiry based teaching approaches. Practicing teachers of agriscience in secondary schools should participate in professional development on how to properly incorporate the teaching methods utilized in this study.

4. Agriscience courses should include direct instruction on the science process skills. This instruction should include a focus on the development of the integrated process skills with a review of the basic science skills.

Recommendations for Further Research

Whereas the variables addressed in this study were able to describe 33% and 36% of the variance in content knowledge and science process skill gain score, respectively, further research is needed to attempt to understand the unaccounted for variance.

Therefore, the following recommendations for further research in this area are provided to act as a guide in this pursuit.

1. As a clinical study, this study should be replicated using procedures that allow a higher degree of randomization and ultimately more generalizability. As noted by Edwards (2003), the research base in agricultural education is dominated by descriptive type research. More research using experimental methods are needed to assist the profession in advancing in the area of agriscience achievement.

2. Research on the relationship between teaching methods, content knowledge, and science process skill achievement of high school students in agricultural education programs should continue. This study should act as a guide with future research is planned and conducted in this area.

3. Moderate correlations were discovered between learning style and science process skill test scores. Additional information on this correlation was not found in the research literature. This relationship warrants further investigation to better explain this phenomenon.

4. In this study, the teaching methods utilized as treatments were used only to deliver content material in the area of plant germination. It is recommended that this study be replicated using other content areas as the focus to determine it this effects the findings.

5. The sample for this study consisted of primarily ninth grade students in an introductory agriscience course. It is recommended that this study be replicated on a wider student population in agricultural education. This type of study should investigate the effect of age and number of agriscience courses has on student achievement in the area of content knowledge achievement and science process skill development.

6. This study was conducted over a relatively short time period. It is recommended that this study be replicated including a longer treatment period to investigate the effectiveness of these methods more thoroughly. Furthermore, it was noted by teachers that students were not familiar with learning in a classroom environment that utilized the investigative approach. By increasing the treatment time, students in this treatment group could become more accustomed to the teaching method.

7. This study examined only the effect of the teaching methods on content knowledge achievement and science process skill achievement, as measured directly following instruction. It is recommended that this study be replicated to investigate the effects of these treatments on both short-term and long-term retention of content knowledge and science process skill.

8. This study did not assess student attitude toward the various methods of instruction. Further research should be conducted to determine how these various teaching method effect student motivation and self-efficacy.

9. Given the number of upper classmen that were found to be enrolled in this introductory agriscience course, further research should be conducted to determine the effect of awarding science credit for graduation in agriscience courses on student enrollment demographics.

APPENDIX A
TREATMENT DELIVERY ANALYSIS SCORESHEETS

Subject Matter Approach

Teacher ID Number: ______________ Lesson Number: _______________

Points Awarded	Points Allowed	
_______	(2 pts)	1. Was new subject matter provided in small chunks?
_______	(2 pts)	2. Was student progress/understanding checked following each presentation? How? ____ Oral questions ____ Student written summaries (journals) ____ Think/pair/share ____ Group discussions ____ Written exam/quiz ____ Student worksheet(s) ____ Other:
_______	(2 pts)	3. Did the instructor provide students with feedback? How? ____ Oral comments ____ Written comments
_______	(2 pts)	4. Were students provided an opportunity for independent practice?
_______	(2 pts)	5. Did the instructor provide a review of new subject matter?
_______	(- 5 pts)	6. Were laboratory exercises used as part of this lesson

Prescriptive Laboratory Approach

Teacher ID Number: _______________ Lesson Number: ________________

Points Awarded	Points Allowed	
________	(1 pts)	1. Was new subject matter provided in small chunks?
________	(1 pts)	2. Was student progress/understanding checked following each presentation? How? ____ Oral questions ____ Student written summaries (journals) ____ Think/pair/share ____ Group discussions ____ Written exam/quiz ____ Student worksheet(s) ____ Other:
________	(4 pts)	3. Did the instructor provide students with step-by-step instructions on how to complete the laboratory activity?
________	(2 pts)	4. Did the instructor provide students with feedback? How? ____ Oral comments ____ Written comments
________	(2 pts)	5. Did the instructor provide a review of new subject matter?

Investigative Laboratory Approach

Teacher ID Number: ______________ Lesson Number: _______________

Points Awarded	Points Allowed	
_______	(1 pts)	1. Was new subject matter provided in small chunks?
_______	(1 pts)	2. Was student progress/understanding checked following each presentation? How? ____ Oral questions ____ Student written summaries (journals) ____ Think/pair/share ____ Group discussions ____ Written exam/quiz ____ Student worksheet(s) ____ Other:
_______	(4 pts)	3. Did the instructor allow students to design their own procedures to complete the laboratory activity?
_______	(2 pts)	4. Did the students report their results to the rest of the class?
_______	(1 pts)	5. Did the instructor provide students with feedback? How? ____ Oral comments ____ Written comments
_______	(1 pts)	6. Did the instructor provide a review of new subject matter?

APPENDIX B
INSTRUCTIONAL PLANS

Subject Matter Approach

Course:	Agriscience Foundations I
Lesson:	Scientific Method (06.00.SM)

Objectives:

1. Identify the steps involved in the scientific method of investigation.
2. Define common terms used in agriscience research.
3. Properly report scientific findings.

Student Performance Standards Addressed:

04.01 - 04.05 - 04.06

Equipment, Supplies, References, and Other Resources:

References:

- Cooper, E. L. & Burton, L. D. (2004) *Agriscience: Fundamentals and applications* (3rd Edition). Albany, NY: Delmar. (Unit 1).
- Osborne, E. W. (1994). *Biological science applications in agriculture*. Danville, IL: Interstate Publishers, Inc. (Chapter 1).

Handouts:

- "The Experimentation Process" handout

Video:

- Teaching Demonstration

Computer and video projection equipment:

- PowerPoint presentation or Overhead projector
    - TM: 06.00.A The Scientific Method
    - TM: 06.00.B Agriscience Terms
    - TM: 06.00.C Guidelines for Constructing Charts and Graphs

Equipment & Supplies:

- Audio recorder
- Audio tapes

Teacher Directions	Content Outline and/or Procedures
REVIEW	None – new unit
INTEREST APPROACH	***Push "record" on audio recorder*** Ask the students to explain the process by which scientists conduct investigations. Ask them to create a step by step procedure. Then ask for volunteers to share their procedure with the rest of the class. Compare student examples with the procedure suggested in the lesson.
OBJECTIVES	
1. Identify the steps involved in the scientific method of investigation. TM: 06.00.A The Scientific Method	A. The scientific method has five steps. 1. Define the problem—usually stated as a question. a. What do you want to know? 2. Gather ***data*** (facts and information) about the problem. a. Summarize past experiences. b. Review other research results. 3. Suggest possible answers or solutions. a. A ***hypothesis*** is a prediction of the results of an experiment. b. Write the hypothesis before beginning the experiment. 4. Test the hypothesis. a. Conduct an experiment to test the hypothesis. b. Summarize the data collected in organized charts or tables. 5. Evaluate the results. a. Examine the findings of the experiment. b. Draw ***conclusions*** or judgments made on the basis of the findings.
2. Define common terms used in agriscience research. TM: 06.00.B Agriscience Terms	B. Key terms used in agriscience experiments 1. <u>Independent variable</u>: Will affect another variable a. Known as *treatment* 2. <u>Dependent variable</u>: Observed variable; expected to change due to independent variable 3. <u>Replication</u> - exact duplication a. Allows for validation
3. Properly report scientific findings	C. Data may be summarized and reported in many different ways.

Teacher Directions	Content Outline and/or Procedures
TM: 06.00.C Guidelines for Constructing Charts and Graphs	1. Descriptive statistics are one common method. Common descriptive statistics are: a. Means – which are averages b. Frequency distributions – which are simply counts of how many times something occurred. c. Percentages 2. Data can be visually summarized using charts and graphs. When constructing a graph, there are certain guidelines to follow: a. The independent variable (X) is reported on the horizontal axis (x-axis). b. The dependent variable (Y) is reported on the vertical axis (y-axis). c. Be sure to label the axis and title the graph.
REVIEW/SUMMARY	Use questioning to determine if students understand the content material of this lesson
APPLICATION	

Course: Agriscience Foundations I

Lesson: Examining Plant Structures and Functions (06.01.SM)

Objectives:

4. Describe the cellular structure of plants.
5. Identify the major parts of plants and explain their functions.
6. Distinguish between plants based on seed cotyledons.
7. Explain the absorption and transport systems of plants.

Student Performance Standards Addressed:

06.01: Describe the structure functions of plant parts including roots, stems, leaves, and flowers.

Equipment, Supplies, References, and Other Resources:

References:

- Cooper, Elmer L. *Agriscience Fundamentals and Applications*, Third Edition. Albany, New York: Delmar Publishers, Inc., 2004.
- Lee, Jasper S. and Diana L. Turner. *AgriScience,* Third Edition. Danville, Illinois: Interstate Publishers, Inc., 2003.

Video:

- Teaching Demonstration

Computer and video projection equipment:

- PowerPoint presentation or Overhead projector
    - TM: 06.01.A Major Parts of a Plant Cell
    - TM: 06.01.B Functions of Leaves, Stems, Roots, and Flowers
    - TM: 06.01.C Parts of a Typical Stem
    - TM: 06.01.E Specialized Stems
    - TM: 06.01.F Kinds of Roots
    - TM: 06.01.G Leaf types
    - TM: 06.01.H Comparison of Monocot and Dicot Seed
    - TM: 06.01.K Arrangement of Tissues in Stems
    - TM: 06.01.L Roots
    - TM: 06.01.M Absorption
    - TM: 06.01.N Stomata

Equipment & Supplies:

- Plant specimen (Interest Approach)
- Audio recorder
- Audio tapes

Teacher Directions	Content Outline and/or Procedures
REVIEW	None – new unit

Teacher Directions	Content Outline and/or Procedures
INTEREST APPROACH	***Push "record" on audio recorder*** Bring a small plant specimen (about 18 inches long) that has been pulled up so that leaves, stems, and roots are obvious. A specimen with flowers and/or fruit is preferred. Ask students to name the different parts of the specimen. As they do, have them describe the function of the part and how it is useful to humans. Move from the interest approach into the objectives and anticipated problems for the lesson.
OBJECTIVES	
1. Describe the cellular structure of plants. TM: 06.01. A Major Parts of a Plant Cell	I. Cells are the structural basis of all living organisms. A. A cell is a tiny structure that forms the basic building blocks of plants. 1. All organisms are made of one or more cells. 2. Protoplasm in cells carries out life processes. B. Plants are multi-cellular organisms, meaning that they have many cells. 1. Some cells have specific functions. 2. Cell specialization is the presence of cells that perform unique activities for a plant. (Flowers, leaves, roots, and stems are made of specialized cells.) C. Cells are formed into groups that work together. 1. Tissue is formed by groups of cells that are alike in activity and structure. 2. An organ is formed by tissues that work together to perform specific functions. 3. An organ system is a group of organs that works together to perform a function. D. Cell structure is the organization of the material that forms a cell. 1. Plant cells have three major parts: wall, nucleus, and cytoplasm.

Teacher Directions	Content Outline and/or Procedures
	2. The cell wall surrounds the cell and controls the movement of materials into and out of the cell. 3. The nucleus is near the center of a cell and contains protoplasm, chromosomes, and other structures that control cell activity. 4. The cytoplasm is a thick solution inside the cell wall surrounding the nucleus. 5. Plant cells have many additional parts, including: chloroplasts, nucleolus, vacuole, mitochondria, and golgi body.
2. Identify the major parts of plants and explain their functions. TM: 06.01.B Functions of Leaves, Stems, Roots, and Flowers TM: 06.01.C Parts of a Typical Stem TM: 06.01.E Specialized Stems	II. Plants are comprised of vegetative and reproductive parts. A. The major vegetative parts of plants are stems, leaves, and roots. 1. A stem is the central axis that supports the leaves, connects them with the roots, and transports water and other materials between the leaves and roots. Stems vary widely in appearance based on the species of plant. Stems may be vertical or horizontal and modified for climbing and to store water and food. Several specialized kinds of stems are important: a. Rhizome—A rhizome is an underground stem that grows horizontally. It may grow adventitious roots and stems to develop as a separate plant. Examples include iris and wild ginger. b. Tuber—A tuber is an enlarged part of a stem that grows underground. A tuber can develop into a separate plant. Examples include potatoes and yams. c. Tendril—A tendril is a threadlike leafless growth on a stem that attaches itself around other stems and objects. Tendrils typically grow in a spiral shape. After attaching itself, it holds the stem in position. Vines and climbing plants often have tendrils. Examples include sweet peas and cucumbers. d. Stolon—A stolon is an above ground stem that grows horizontally and propagates new plants.

Teacher Directions	Content Outline and/or Procedures
	Strawberries are well known as examples of plants that multiply using stolons.
	e. Bulb—A bulb is an underground food-storage organ consisting of flattened, fleshy stem-like leaves with roots on the lower side. Examples of bulbs are onions and daffodils.
TM: 06.01.F Kinds of Roots	f. Corm—A corm is a food storage structure at the end of a stem that grows underground. It is an enlarged or swollen stem base. Examples include gladiolus and crocus.
	g. Cladophyll—A cladophyll is a leaflike branch that resembles a leaf. It is also called a cladode. A cladophyll functions much like a leaf.
TM: 06.01.G Leaf types	2. A root is the part of a plant that grows in the soil or other media. Roots anchor plants, absorb water and minerals, and store food. The root system structure varies widely depending on the species of plant. Overall, roots can be classified as two major types:
	a. Fibrous—A fibrous root system is made of many small roots and spread throughout the soil.
	b. Taproot—A taproot system is made of one primary root with a number of small secondary roots.
	3. A leaf is typically a large, flat, green organ attached to the stem. Leaves carry out photosynthesis, transpiration, and may store food. Shape, arrangement, and other features vary widely with the species of plant. There are two major kinds of leaves and three major types of arrangements:
	a. Simple—A simple leaf has only one blade.
TM: 06.01.B Functions of Leaves, Stems, Roots, and Flowers	b. Compound—A compound leaf is divided into two or more leaflets
	c. Leaf attachment also varies. This refers to the spacing and arrangement of leaves on the stem of a plant. The major kinds of attachment are:

Teacher Directions	Content Outline and/or Procedures
	(1) Alternate—Alternate leaf arrangement is one leaf at each node on a stem. (2) Opposite—Opposite leaf arrangement is two leaves are attached at nodes opposite each other. (3) Whorled—Whorled leaf arrangement is three or more leaves are at each node. B. The major reproductive parts of plants are flowers, seed, and fruit. 1. A flower is a part containing the reproductive organs. The types of flowers vary considerably. In general, flowers produce pollen and ovules. Fertilization occurs when a pollen cell unites with an ovule. 2. Seed are formed by fertilized ovules and contain new plant life. 3. Fruit are the ovaries which develop to protect and nourish the developing seed. The kinds and nature of fruit vary widely.
3. Distinguish between plants based on seed cotyledons. TM: 06.01.H Comparison of Monocot and Dicot Seed	III. A cotyledon is the fleshy structure within a seed that contains food for a developing embryo. A. Depending on the plant species, a seed may have one or two cotyledons. B. A plant species producing seed with one cotyledon is a monocotyledon, or monocot. 1. All grasses are monocots. Corn, wheat, oats, Bermuda grass, and sugarcane are examples of monocots. 2. Monocot plants have long, narrow leaves with parallel veins. All leaves branch from the main stem. 3. Stems are non-woody and tend to have a large area of pith in the center. C. A plant species producing seed with two cotyledons is a dicotyledon, or dicot. 1. All plants other than grasses are dicots. Soybeans, trees,

Teacher Directions	Content Outline and/or Procedures
	lettuce, sunflowers, and petunias are examples of dicots. 2. Dicot plants have broad leaves with a net-type of veins. 3. Stems are often long and branching. They may be woody or non-woody, depending on the plant species.
4. Explain the absorption and transport systems of plants. TM: 06.01.K Arrangement of Tissues in Stems TM: 06.01.L Roots TM: 06.01.M Absorption TM: 06.01.N Stomata	IV. Water and nutrients are primarily absorbed by the roots and transported throughout the plant by various tissues in the roots, stems, and leaves. A. Roots have tiny root hairs covered with thin membranes that allow water and nutrients to enter. 1. Osmosis is the movement of water from greater concentration in the soil or media to lower concentration in the root. 2. Water enters until the concentration in the root is equal to the concentration outside the root. 3. The water entering roots also carries inorganic substances known as nutrients. B. After absorption by roots, water is passed from cell to cell until it reaches the xylem. 1. Xylem is tissue, formed as tubes, that conducts water up the stem and to the leaves. 2. The petiole of the leaf takes the water from the xylem in the stem to the leaf veins, which distribute it throughout the leaf. C. Leaves lose water by transpiration. 1. Transpiration occurs through tiny stomata on leaves. 2. Transpiration creates somewhat of an upward pull that assists the xylem in moving water and nutrients. D. Manufactured food is conducted from the leaves through the stems to the roots in phloem tissue. 1. Phloem is the tissue that conducts sugars, proteins, hormones, dissolved materials, and salts from leaves to other

Teacher Directions	Content Outline and/or Procedures
	parts of a plant. 2. The structure is observed as elongated sieve-type cells that form tube structures in stems.
REVIEW/SUMMARY	Focus the review and summary of the lesson on the student learning objectives. Have students explain the content associated with each objective. Use specimens of plant materials for students to use in demonstrating their knowledge of the objectives. Use student responses as the basis for reteaching. Complete Examining Plant Structures and Functions worksheet and/or have students complete questions at the end of the chapters in the text.
APPLICATION	

Course:	Agriscience Foundations I
Lesson:	Determining the Importance of Photosynthesis and Respiration (06.02.SM)

Objectives:

1. Explain photosynthesis and its importance.
2. Write the chemical equation for photosynthesis and explain it.
3. Explain how light and dark reactions differ.
4. Define respiration and explain why it is important.
5. List four factors that affect the rate of respiration.
6. Explain the importance of transpiration to plants.

Student Performance Standards Addressed:

06.02: Describe the processes of plant growth including photosynthesis, respiration, and nutrient uptake.

Equipment, Supplies, References, and Other Resources:

References:

- Cooper, Elmer L. *Agriscience Fundamentals and Applications*, Third Edition. Albany, New York: Delmar Publishers, Inc., 2004.
- Lee, Jasper S. and Diana L. Turner. *AgriScience,* Third Edition. Danville, Illinois: Interstate Publishers, Inc., 2003.

Video:

- Teaching Demonstration

Computer and video projection equipment:

- PowerPoint presentation or Overhead projector
  - TM: 06.02.A Energy Flow
  - TM: 06.02.B Photosynthesis Equation
  - TM: 06.02.C Two Major Phases of Photosynthesis
  - TM: 06.02.D Comparison of Photosynthesis and Respiration
  - TM: 06.02.E Factors Affecting the Rate of Respiration
  - TM: 06.02.F Transpiration and Gas Exchange in Leaves
  - TM: 06.02.G Factors Affecting the Rate of Transpiration

Equipment & Supplies:

- Audio recorder
- Audio tapes

Teacher Directions	Content Outline and/or Procedures
REVIEW	***Push "record" on audio recorder*** Quickly review the objectives of Lesson 06.01.SM Examining Plant Structures and Functions.

Teacher Directions	Content Outline and/or Procedures
INTEREST APPROACH	Start the lesson by shutting off the lights in the classroom. Ask the students if they could survive and continue to make energy if they were kept in the dark. Ask students what effect complete darkness would have on other mammals. Now ask the students what effect complete darkness would have on plants.
OBJECTIVES	
1. *Explain photosynthesis and its importance.* TM: 06.02.A Energy Flow TM: 06.02.C Two Major Phases of Photosynthesis TM: 06.02.B Photosynthesis Equation	I. Photosynthesis is the manufacture of food by plant cells. A. Sugar is the major product of photosynthesis and provides energy for the plant. B. There are two phases to the photosynthesis process. 1. Energy gathering—Plant leaves soak up sunlight. 2. Sugar making—Plants convert energy from sunlight into stored chemical energy. a. Chemical energy rearranges carbon dioxide in the plant in the presence of chlorophyll to form sugar. b. Glucose, a simple sugar, is formed. C. Photosynthesis is the most important reaction on earth. All life forms are dependent on the reaction. 1. Occurs in the chloroplasts 2. CO_2 + light + chlorophyll + H_2O _ $C_6H_{12}O_6$ (glucose) + H_2O + O_2 D. In order for photosynthesis to occur, several things must be present. 1. Chlorophyll—green colored substance in plants. 2. Light—Leaves absorb necessary energy from the sun's rays or artificial light. 3. Carbon Dioxide—Enters the plant through structure called stomata in the leaves. Carbon dioxide is split during photosynthesis. 4. Water—Water is also split during photosynthesis.

Teacher Directions	Content Outline and/or Procedures
2. *Write the chemical equation for photosynthesis and explain it.* TM: 06.02.B Photosynthesis Equation	II. Photosynthesis is a series of chemical reactions that yields sugars, water, and oxygen. A. The chemical equation of photosynthesis can be written in words: Six molecules of carbon dioxide plus twelve molecules of water in combination with a healthy plant and some form of light energy, to make one molecule of sugar plus six molecules of water and six molecules of oxygen. B. The products of photosynthesis include carbohydrates in the form of sugars and starches as well as water and oxygen.
3. *Explain how light and dark reactions differ.*	III. Photosynthesis is a series of complex reactions that have been divided into two major phases. These two major phases have been named the light and dark reactions. A. Light Reactions— 1. The light reactions are also known as light dependent reactions. Light allows energy to be released in the form of ATP which can be used by the plant in the splitting of water and the release of oxygen. 2. The pigments in chloroplasts absorb light energy to form NADPH and ATP to be used in the breakdown of CO2 in the dark reactions. B. Dark Reaction— 1. Also known as light independent reactions. 2. A chemical known as RuBP (rubilose biphosphate) absorbs carbon. Carbon dioxide and RuBP join together and go through a process called the Calvin cycle. The Calvin cycle reduces carbon dioxide to manufacture carbohydrates. The NADPH and ATP synthesis from the light reactions provide the energy needed to power the Calvin cycle. 3. As a result of the Calvin cycle, one molecule of glucose is formed.
4. *Define respiration and explain why it is important.* TM: 06.02.D Comparison of	IV. ***Respiration*** is the process by which an organism provides its cells with oxygen so energy can be released from digested food. Respiration takes place in all living cells at all times. A. ***Mitochondria*** are energy processing factories for plants.

Teacher Directions	Content Outline and/or Procedures
Photosynthesis and Respiration	Respiration takes place in the mitochondria of all cells. B. Respiration yields the opposite results as photosynthesis. The process of photosynthesis absorbs energy, consumes carbon dioxide and releases oxygen. Respiration uses energy, consumes oxygen and releases carbon dioxide.
5. *List four factors that affect the rate of respiration.* TM: 06.02.E Factors Affecting the Rate of Respiration	V. Temperature, oxygen, soil conditions, and light can affect the rate of respiration. A. Temperature—There is a direct relationship between respiration and temperature, as the temperature increases so does the rate of respiration. B. Oxygen—Oxygen is required for respiration to take place. As oxygen levels decrease so does the rate of respiration. C. Soil conditions—Soil containing large quantities of water cause the rate of respiration to decrease because of the lack of oxygen. D. Light—The amount of energy produced by photosynthesis in low light conditions is reduced. Therefore the amount of energy available to conduct respiration is lower.
6. *Explain the importance of transpiration in plants.* TM: 06.02.F Transpiration and Gas Exchange in Leaves TM: 06.02.G Factors Affecting the Rate of Transpiration	VI. ***Transpiration*** in plants is the loss of water by evaporation through structures called stomata. ***Stomata*** are pores or openings in the plant that allow for the exchange of water and other substances. Transpiration in plants is similar to perspiration in humans. A. Water molecules and transpiration together form a force that is essential for water movement through plants. 1. As water evaporates through the stomata of plant, it creates a pull that aids in the absorption of water by the roots. (An analogy of using a straw to drink will help students to visualize this process.) 2. Transpiration is a vital link in the hydrologic cycle. Ninety-nine percent of all water taken in by the plant is lost to transpiration. Therefore, transpiration contributes significantly to the generation of rainfall. B. Factors affecting the rate of transpiration include: 1. Wind speed—the relationship between wind speed and

Teacher Directions	Content Outline and/or Procedures
	transpiration is a direct relationship. 2. Temperature—as temperature increases so does the rate of transpiration because the plant uses transpiration as a mechanism to cool itself. Once again there is a direct relationship between temperature and transpiration. 3. Humidity—Humidity influences the rate of transpiration because if the air is already saturated with water vapor, there will be a decrease in the rate of evaporation. 4. Drought—If the plant is experiencing drought conditions it will close the stomata to prevent needed water from escaping. When the plant's stomata are closed transpiration does not take place.
REVIEW/SUMMARY	Focus the review and summary of the lesson around the student learning objectives. Call on students to explain the content associated with each objective. Questions at the end of each chapter in the recommended textbooks may also be used in the review/summary. Complete the Determining the Importance of Photosynthesis and Respiration worksheet.
APPLICATION	

Course:	Agriscience Foundations I
Lesson:	Propagating Plants Sexually (06.03.SM)

Objectives:

1. Explain sexual reproduction of plants and its importance in plant survival.
2. Explain how pollination occurs and describe the different types of pollination.
3. Explain fertilization in flowering plants.
4. Explain the structures and formation of seeds.
5. Describe the conditions for seed germination.
6. Compare and contrast indoor and outdoor growing conditions.

Student Performance Standards Addressed:

06.03: Propagate plants through sexual and asexual means.

Equipment, Supplies, References, and Other Resources:

References:

- Cooper, Elmer L. *Agriscience Fundamentals and Applications*, Third Edition. Albany, New York: Delmar Publishers, Inc., 2004.
- Lee, Jasper S. and Diana L. Turner. *AgriScience,* Third Edition. Danville, Illinois: Interstate Publishers, Inc., 2003.

Video:

- Teaching Demonstration

Computer and video projection equipment:

- PowerPoint presentation or overhead projector
    - TM: 06.03a.A Pollination of a Flower
    - TM: 06.03a.B Fertilization of a Flower
    - TM: 06.03a.C Parts of a Bean Seed and a Corn Seed
    - TM: 06.03a.D Environmental Factors Necessary for Germination

Equipment & Supplies:

- Examples of perfect flowers (Interest Approach)
- Audio recorder
- Audio tapes

Teacher Directions	Content Outline and/or Procedures
REVIEW	***Push "record" on audio recorder*** Quickly review the objectives of Lesson 06.02.SM Determining the Importance of Photosynthesis and Respiration.
INTEREST APPROACH	Bring a couple of samples of perfect flowers, such as from a Hibiscus or a Lily plant, to class. Use them to show the students the various parts of a flower. Dissect the flower and

Teacher Directions	Content Outline and/or Procedures
	demonstrate to students how the pollen gets from the anther to the stigma and then grows a pollen tube down through the style to fertilize the egg. Students should be able to see how the various parts of the flower interact for pollination to occur.
OBJECTIVES	
1. Explain sexual reproduction of plants and its importance in plant survival.	I. Sexual reproduction involves flowers, fruits, and seeds. A. In sexual reproduction, sperm carried in the pollen from the male flower fuses with the egg in the female part of the flower. Both contribute to the genetic makeup of the new plant. B. Each time sexual reproduction occurs, there is a recombining of genetic material. As a result, some changes will occur. Some may be beneficial and some may not. As conditions of the environment change over time, the beneficial changes in plant genetics will allow the plant to survive. As plants continue to reproduce, they pass genes onto their offspring, which enables them to survive.
2. Explain how pollination occurs and describe the different types of pollination. TM: 06.03a.A Pollination of a Flower	II. Pollination is the transfer of pollen from the male to the female part of a plant. A. Pollination occurs in many different ways: 1. Birds, insects, bats, and other animals are attracted to colorful, scented flowers. As they visit various flowers for food, they unintentionally pick up pollen and carry it from flower to flower. 2. Wind moves pollen from one flower to another. Plants that rely on wind generally do not produce colorful flowers with scents or nectar. B. Pollination of plants may occur in one of two ways: 1. Self-pollination occurs when pollen from a plant pollinates a flower on the same plant. 2. Cross-pollination occurs when pollen from a plant pollinates a flower on a different plant. C. Once pollen lands on the stigma, it grows a pollen tube down the style to the ovary. The cell within the grain of pollen divides to form two sperm nuclei, which travel down

Teacher Directions	Content Outline and/or Procedures
	the pollen tube to the embryo sac, fertilizing the egg.
3. Explain fertilization in flowering plants. TM: 06.03a.B Fertilization of a Flower	III. Fertilization is necessary in flowering plants in order for the seed to develop. A. Fertilization in flowering plants is different from fertilization in any other living organism. In plants, both sperm nuclei in the pollen grain are involved in fertilization, resulting in a double fertilization. 1. The first fertilization occurs when one sperm fuses with the egg, resulting in a zygote. The resulting seed contains genetic information from both the male and female part of the flower. 2. The second fertilization occurs when the second sperm nucleus fuses with the two nuclei in the embryo sac. This will develop into the endosperm. The ovule of the flower will become the seed. B. When fertilization occurs and the parents are genetically different, the resulting offspring is said to be a hybrid. The advantage of hybrids is that the best traits of each parent, such as more vigorous growth, insect and disease resistance, or uniformity, may be expressed in the offspring. C. Genetic information is stored in every cell of a plant in long molecular chains made of Deoxyribonucleic acid (DNA). Segments of DNA, called genes, establish the code for life processes and the appearance of a plant. The genes are arranged in a set of chromosomes. Normal cells contain a double set of chromosomes and are said to be diploid. Reproductive cells, sperm and egg cells, have a single set of chromosomes and are said to be haploid. When fertilization occurs, the single sets of chromosomes are combined into the double set, one from each parent, resulting in traits from each parent being passed on to the offspring.
4. Explain the structures and formation of seeds. TM: 06.03a.C Parts of a Bean Seed and a Corn Seed.	IV. The function of the seed is to grow and develop into a mature plant that will produce more seeds. A. Seeds of flowering plants have several parts. 1. The seed coat is a protective shell surrounding the embryo and endosperm. It protects the seed from drying and from physical injury. The seed coat helps in determining when conditions for germination or the beginning of growth are

Teacher Directions	Content Outline and/or Procedures
	right. 2. The embryo is a little plant that eventually grows and develops into the mature plant. It remains dormant within the seed. It has a stem, root, and one or two seed leaves called cotyledons. Monocot embryos have one seed leaf and dicot embryos have two seed leaves. 3. The endosperm is the food storage tissue in the seed, particularly in monocots. Dicots store their food in the two cotyledons. The food storage is necessary for the young seedling until it is able to manufacture its own food. B. After fertilization, the ovary wall enlarges and forms the fruit. The fruit may be fleshy or dry. 1. Fleshy fruit prevents the seeds from drying until they are mature. They also serve to help disperse the seeds. Animals are attracted to fruit, eat it with the seeds, and disperse or disseminate the seeds somewhere away from the parent plant. Examples of fleshy fruit include tomatoes, apples, pears, etc. 2. Dry fruit is found on plants such as the dandelion and maple trees. It does not depend on animals for dissemination, but may depend on wind or other methods of dissemination.
5. Describe the conditions for seed germination. TM: 06.03a.D Environmental Factors Necessary for Germination	V. Seeds are designed to wait for favorable conditions to begin growth. They may lay dormant for many years before conditions allow them to begin to grow. A. Several environmental factors play key roles in seed germination. 1. Moisture or water is necessary for germination. 2. Air, particularly oxygen, is required for germination. 3. Warm temperatures, between 40 and 104 degrees F, are necessary for germination. 4. Some plants require light or total darkness for germination. B. Stratification is when the seed must go through a period of cold temperatures before it will germinate. C. Scarification is the breaking down of the seed coat. Some

Teacher Directions	Content Outline and/or Procedures
	seeds have such a hard, thick seed coat that they prevent the absorption of water to enable germination to occur. D. The germination process begins with the absorption of water. The seed swells and the embryo changes from a dormant state to an actively growing plant. The embryo draws energy from starches stored in the endosperm or cotyledons. The embryo's root emerges from the seed and develops into the primary root. Then, the stem of the embryo sprouts upward. E. The quality of seed used is very important in production agriculture. Viable, or live, seed is important to ensure a high percentage of seed germination. Seed companies test seed to determine its germination percentage, which must be printed on the seed bag. Proper humidity and temperature during storage of the seeds help maintain seed viability. 5. High salt concentrations in the soil can have adverse effects on plant growth. A. Soil salinity is most severe in arid, irrigated areas around the world. Salinity may affect as much as 30% of all irrigated land in the U.S., primarily in the southwestern part of the country. B. In field conditions dissolved salts are usually applied in the irrigation water. Enough salt may accumulate in a few years to reduce the productivity of the soil. Standard practice in irrigation is to add enough water to permit some drainage to help remove salt buildup in the soil. Artificial drainage is a major investment. Research now underway is aimed at determining optimal amounts of irrigated water to apply, and developing simple methods of measuring soil salinity concentrations in the soil. C. Salt buildup may also be a problem in greenhouse crops and indoor plants if drainage outlets are not provided in the growing container. Inadequate watering, even with well designed containers, can lead to salt buildup in the growing medium and eventual death of the plant.
6. Compare and contrast indoor and outdoor growing conditions.	VI. The grower has control over the quality and condition of seed, planting procedure, and weed competition, environmental conditions cannot be controlled in outdoor

Teacher Directions	Content Outline and/or Procedures
	settings. The grower must be able to correctly interpret planting conditions and adjust timing and planting procedures accordingly. A. A major advantage of growing plants in greenhouses is that critical environmental conditions of moisture, temperature, oxygen and light can accurately be controlled. Control and/or correct adaptation to environmental conditions enhance overall seed germination and seedling establishment. Germination percentage affects plant population, which in turn affects profit potential of a given crop. B. In outdoor settings soil and seedbed conditions have a direct influence on moisture and oxygen availability for seed germination in vegetable, agronomic and horticulture crops. In addition, all plants have soil temperature ranges that will promote acceptable germination rates. Thus, growers must know the temperature ranges for their crops and time their plantings accordingly in order to ensure good germination and seedling establishment.
REVIEW/SUMMARY	Use the student learning objectives to summarize the lesson. Have students explain the content associated with each objective. Student responses can be used in determining which objectives need to be reviewed or taught from a different perspective. Questions at the end of chapters of textbooks covering this material may also be used in the review/summary. Complete Propagating Plants Sexually Worksheet.
APPLICATION	

Prescriptive Laboratory Approach

Course: Agriscience Foundations I

Lesson: Scientific Method (06.00.PL)

Objectives:

1. Identify the steps involved in the scientific method of investigation.
2. Define common terms used in agriscience research.
3. Properly report scientific findings.

Student Performance Standards Addressed:

04.01 - 04.05 - 04.06

Equipment, Supplies, References, and Other Resources:

References:

- Cooper, E. L. & Burton, L. D. (2004) *Agriscience: Fundamentals and applications* (3rd Edition). Albany, NY: Delmar. (Unit 1).
- Osborne, E. W. (1994). *Biological science applications in agriculture*. Danville, IL: Interstate Publishers, Inc. (Chapter 1).

Handouts:

- "The Experimentation Process" handout
- LS: 06.00.PL Determining Mass Student Handout

Video:

- Teaching Demonstration

Computer and video projection equipment:

- PowerPoint presentation or Overhead projector
    - TM: 06.00.A The Scientific Method
    - TM: 06.00.B Agriscience Terms
    - TM: 06.00.C Guidelines for Constructing Charts and Graphs

Equipment & Supplies:

- See materials list on lab sheet
- Audio recorder
- Audio tapes

Teacher Directions	Content Outline and/or Procedures
REVIEW	None – new unit
INTEREST APPROACH	***Push "record" on audio recorder*** Ask the students to explain the process by which scientists conduct investigations. Ask them to create a step by step procedure. Then ask for volunteers to share their procedure with the rest of the class. Compare student examples with the procedure suggested in the lesson.

Teacher Directions	**Content Outline and/or Procedures**
OBJECTIVES	
1. Identify the steps involved in the scientific method of investigation. TM: 06.00.A – The Scientific Method	A. The scientific method has five steps. 1. Define the problem—usually stated as a question. a. What do you want to know? 2. Gather ***data*** (facts and information) about the problem. a. Summarize past experiences. b. Review other research results. 3. Suggest possible answers or solutions. a. A ***hypothesis*** is a prediction of the results of an experiment. b. Write the hypothesis before beginning the experiment. 4. Test the hypothesis. a. Conduct an experiment to test the hypothesis. b. Summarize the data collected in organized charts or tables. 5. Evaluate the results. a. Examine the findings of the experiment. b. Draw ***conclusions*** or judgments made on the basis of the findings.
2. Define common terms used in agriscience research. TM: 06.00.B – Agriscience Terms	B. Key terms used in agriscience experiments 1. <u>Independent variable</u>: Will affect another variable a. Known as *treatment* 2. <u>Dependent variable</u>: Observed variable; expected to change due to independent variable 3. <u>Replication</u> - exact duplication a. Allows for validation
3. Properly report scientific findings TM: 06.00.C – Guidelines for	C. Data may be summarized and reported in many different ways. 1. Descriptive statistics are one common method. Common descriptive statistics are: a. Means – which are averages b. Frequency distributions – which are simply counts of how many times something occurred. c. Percentages

Teacher Directions	Content Outline and/or Procedures
Constructing Charts and Graphs	2. Data can be visually summarized using charts and graphs. When constructing a graph, there are certain guidelines to follow: a. The independent variable (X) is reported on the horizontal axis (x-axis). b. The dependent variable (Y) is reported on the vertical axis (y-axis). c. Be sure to label the axis and title the graph.
REVIEW/SUMMARY	Use questioning to determine if students understand the content material of this lesson
APPLICATION	Complete LS 06.00.PL Determining Mass

Determining Mass

Interest Approach: ***(Present as follows.)***

Ask students, "What is mass?" Select a few students to offer their definition. Then hold up a piece of bubble gum and ask the students, "What will happen to the mass (weight) of this piece of bubble gum when I chew it?"

Research Problem: ***(Discuss.)***

What effect does chewing have on the mass of bubble gum?

Purpose: ***(Present to class and discuss.)***

The purpose of this experiment is to observe the effect chewing has on the mass of bubble gum. Also, this experiment will familiarize students with the scientific method.

Materials: ***(Give to students.)***

- Balances or scales
- Bubble gum
- Graph paper

Procedures: ***(Give a copy to students and have them conduct the experiment.)***
(2-4 students per group)

1. Weigh one piece of bubble gum. Record the mass.
2. Develop a hypothesis on the effect chewing will have on the mass of the bubble gum. Record your hypothesis.
3. Chew the bubble gum for 30 seconds. Using the wrapper as a weigh paper, determine the mass of the bubble gum.
4. Repeat step #3 until bubble gum has been chewed for 5 minutes.
5. Graph the results of your findings. ***(Be sure students have properly identified the independent and dependent variables and that the graphs are labeled appropriately.)***
6. Evaluate hypothesis

Data Summary: **(Give sample data table to students and lead a discussion on how to summarize the data from other parts of the experiment.)**

Observations should be taken of the experiment at regular intervals. Have students complete a simple data summary table stating their observations.

Sample Data Summary Table

Time	0:00	0:30	1:00	1:30	2:00	2:30	3:00	3:30	4:00	4:30	5:00
Mass											

Conclusions: ***(Lead a discussion of these and other conclusions.)***

1. Mass of the bubble gum decreased as it was chewed.
2. The decline in mass was greatest in the beginning. As time passed, the rate of decline slowed.

Discussion: ***(Use a supervised study session or whole class discussion to answer the following questions.)***

1 What were the most difficult aspects of conducting this experiment?
2. Did the experimental procedures produce the desired results? (Were you able to answer the research question?)
3. What would you do differently in conducting this experiment a second time?
4. Why did the rate at which the mass changed slow down?

Further Investigation: ***(Lead a discussion of these and other ideas.)***

1 Compare different types of gum.
2. Instead of using time as the dependent variable, count the number of chews.

Questions: ***(Lead a discussion of these and other questions.)***

What was your hypothesis? Was it correct?

What is the dependent variable in this experiment? ***Answer: Time***

What is the independent variable in this experiment? ***Answer: Mass***

LS: 06.00.PL **Student Handout**

Determining Mass

Purpose:

The purpose of this experiment is to observe the effect chewing has on the mass of bubble gum. Also, this experiment will familiarize students with the scientific method.

Research Problem: *(Discuss.)*

What effect does chewing have on the mass of bubble gum?

Your hypothesis is:

Materials:

- Balances or scales
- Bubble gum
- Graph paper

Procedures:

1. Weigh one piece of bubble gum. Record the mass.
2. Develop a hypothesis on the effect chewing will have on the mass of the bubble gum. Record your hypothesis.
3. Chew the bubble gum for 30 seconds. Using the wrapper as a weigh paper, determine the mass of the bubble gum.
4. Repeat step #3 until bubble gum has been chewed for 5 minutes.
5. Graph the results of your findings.
6. Evaluate hypothesis

Data Summary:

Observations should be taken of the experiment at regular intervals. Complete the following data summary table stating your observations.

Data Summary Table

Time	0:00	0:30	1:00	1:30	2:00	2:30	3:00	3:30	4:00	4:30	5:00
Mass											

Questions:

What was your hypothesis? Was it correct?
What is the dependent variable in this experiment?
What is the independent variable in this experiment?

Course: Agriscience Foundations I

Lesson: Examining Plant Structures and Functions (06.01.PL)

Objectives:

1. Describe the cellular structure of plants.
2. Identify the major parts of plants and explain their functions.
3. Distinguish between plants based on seed cotyledons.
4. Explain the absorption and transport systems of plants.

Student Performance Standards Addressed:

06.01: Describe the structure functions of plant parts including roots, stems, leaves, and flowers.

Equipment, Supplies, References, and Other Resources:

References:

- Cooper, Elmer L. *Agriscience Fundamentals and Applications*, Third Edition. Albany, New York: Delmar Publishers, Inc., 2004.
- Lee, Jasper S. and Diana L. Turner. *AgriScience,* Third Edition. Danville, Illinois: Interstate Publishers, Inc., 2003.

Handouts:

- Lab Sheet 06.01.PL Osmotic Turgescence (Pressure) Student Handout

Video:

- Teaching Demonstration

Computer and video projection equipment:

- PowerPoint presentation or Overhead projector
    - TM: 06.01.A Major Parts of a Plant Cell
    - TM: 06.01.B Functions of Leaves, Stems, Roots, and Flowers
    - TM: 06.01.C Parts of a Typical Stem
    - TM: 06.01.E Specialized Stems
    - TM: 06.01.F Kinds of Roots
    - TM: 06.01.G Leaf types
    - TM: 06.01.H Comparison of Monocot and Dicot Seed
    - TM: 06.01.K Arrangement of Tissues in Stems
    - TM: 06.01.L Roots
    - TM: 06.01.M Absorption
    - TM: 06.01.N Stomata

Equipment & Supplies:

- Plant specimen (Interest Approach)
- See materials list on lab sheet
- Audio recorder
- Audio tapes

Teacher Directions	Content Outline and/or Procedures
REVIEW	None – new unit
INTEREST APPROACH	***Push "record" on audio recorder*** Bring a small plant specimen (about 18 inches long) that has been pulled up so that leaves, stems, and roots are obvious. A specimen with flowers and/or fruit is preferred. Ask students to name the different parts of the specimen. As they do, have them describe the function of the part and how it is useful to humans. Move from the interest approach into the objectives and anticipated problems for the lesson.
OBJECTIVES	
1. Describe the cellular structure of plants. TM: 06.01. A Major Parts of a Plant Cell	I. Cells are the structural basis of all living organisms. A. A cell is a tiny structure that forms the basic building blocks of plants. 1. All organisms are made of one or more cells. 2. Protoplasm in cells carries out life processes. B. Plants are multi-cellular organisms, meaning that they have many cells. 1. Some cells have specific functions. 2. Cell specialization is the presence of cells that perform unique activities for a plant. (Flowers, leaves, roots, and stems are made of specialized cells.) C. Cells are formed into groups that work together. 1. Tissue is formed by groups of cells that are alike in activity and structure. 2. An organ is formed by tissues that work together to perform specific functions. 3. An organ system is a group of organs that works together to perform a function. D. Cell structure is the organization of the material that forms a cell. 1. Plant cells have three major parts: wall, nucleus, and

Teacher Directions	Content Outline and/or Procedures
	cytoplasm. 2. The cell wall surrounds the cell and controls the movement of materials into and out of the cell. 3. The nucleus is near the center of a cell and contains protoplasm, chromosomes, and other structures that control cell activity. 4. The cytoplasm is a thick solution inside the cell wall surrounding the nucleus. 5. Plant cells have many additional parts, including: chloroplasts, nucleolus, vacuole, mitochondria, and golgi body.
2. Identify the major parts of plants and explain their functions. TM: 06.01.B Functions of Leaves, Stems, Roots, and Flowers TM: 06.01.C Parts of a Typical Stem TM: 06.01.E Specialized Stems	II. Plants are comprised of vegetative and reproductive parts. A. The major vegetative parts of plants are stems, leaves, and roots. 1. A stem is the central axis that supports the leaves, connects them with the roots, and transports water and other materials between the leaves and roots. Stems vary widely in appearance based on the species of plant. Stems may be vertical or horizontal and modified for climbing and to store water and food. Several specialized kinds of stems are important: a. Rhizome—A rhizome is an underground stem that grows horizontally. It may grow adventitious roots and stems to develop as a separate plant. Examples include iris and wild ginger. b. Tuber—A tuber is an enlarged part of a stem that grows underground. A tuber can develop into a separate plant. Examples include potatoes and yams. c. Tendril—A tendril is a threadlike leafless growth on a stem that attaches itself around other stems and objects. Tendrils typically grow in a spiral shape. After attaching itself, it holds the stem in position. Vines and climbing plants often have tendrils. Examples include sweet peas and cucumbers.

Teacher Directions	Content Outline and/or Procedures
	d. Stolon—A stolon is an above ground stem that grows horizontally and propagates new plants. Strawberries are well known as examples of plants that multiply using stolons. e. Bulb—A bulb is an underground food-storage organ consisting of flattened, fleshy stem-like leaves with roots on the lower side. Examples of bulbs are onions and daffodils.
TM: 06.01.F Kinds of Roots	f. Corm—A corm is a food storage structure at the end of a stem that grows underground. It is an enlarged or swollen stem base. Examples include gladiolus and crocus. g. Cladophyll—A cladophyll is a leaflike branch that resembles a leaf. It is also called a cladode. A cladophyll functions much like a leaf.
TM: 06.01.G Leaf types	2. A root is the part of a plant that grows in the soil or other media. Roots anchor plants, absorb water and minerals, and store food. The root system structure varies widely depending on the species of plant. Overall, roots can be classified as two major types: a. Fibrous—A fibrous root system is made of many small roots and spread throughout the soil. b. Taproot—A taproot system is made of one primary root with a number of small secondary roots. 3. A leaf is typically a large, flat, green organ attached to the stem. Leaves carry out photosynthesis, transpiration, and may store food. Shape, arrangement, and other features vary widely with the species of plant. There are two major kinds of leaves and three major types of arrangements: a. Simple—A simple leaf has only one blade.
TM: 06.01.B Functions of Leaves, Stems, Roots, and Flowers	b. Compound—A compound leaf is divided into two or more leaflets c. Leaf attachment also varies. This refers to the spacing and arrangement of leaves on the stem of a plant. The major kinds of attachment

Teacher Directions	Content Outline and/or Procedures
	are: (1) Alternate—Alternate leaf arrangement is one leaf at each node on a stem. (2) Opposite—Opposite leaf arrangement is two leaves are attached at nodes opposite each other. (3) Whorled—Whorled leaf arrangement is three or more leaves are at each node. B. The major reproductive parts of plants are flowers, seed, and fruit. 1. A flower is a part containing the reproductive organs. The types of flowers vary considerably. In general, flowers produce pollen and ovules. Fertilization occurs when a pollen cell unites with an ovule. 2. Seed are formed by fertilized ovules and contain new plant life. 3. Fruit are the ovaries which develop to protect and nourish the developing seed. The kinds and nature of fruit vary widely.
3. Distinguish between plants based on seed cotyledons. TM: 06.01.H Comparison of Monocot and Dicot Seed	III. A cotyledon is the fleshy structure within a seed that contains food for a developing embryo. A. Depending on the plant species, a seed may have one or two cotyledons. B. A plant species producing seed with one cotyledon is a monocotyledon, or monocot. 1. All grasses are monocots. Corn, wheat, oats, Bermuda grass, and sugarcane are examples of monocots. 2. Monocot plants have long, narrow leaves with parallel veins. All leaves branch from the main stem. 3. Stems are non-woody and tend to have a large area of pith in the center. C. A plant species producing seed with two cotyledons is a

Teacher Directions	Content Outline and/or Procedures
	dicotyledon, or dicot. 1. All plants other than grasses are dicots. Soybeans, trees, lettuce, sunflowers, and petunias are examples of dicots. 2. Dicot plants have broad leaves with a net-type of veins. 3. Stems are often long and branching. They may be woody or non-woody, depending on the plant species.
4. Explain the absorption and transport systems of plants. TM: 06.01.K Arrangement of Tissues in Stems TM: 06.01.L Roots TM: 06.01.M Absorption TM: 06.01.N Stomata	IV. Water and nutrients are primarily absorbed by the roots and transported throughout the plant by various tissues in the roots, stems, and leaves. A. Roots have tiny root hairs covered with thin membranes that allow water and nutrients to enter. 1. Osmosis is the movement of water from greater concentration in the soil or media to lower concentration in the root. 2. Water enters until the concentration in the root is equal to the concentration outside the root. 3. The water entering roots also carries inorganic substances known as nutrients. B. After absorption by roots, water is passed from cell to cell until it reaches the xylem. 1. Xylem is tissue, formed as tubes, that conducts water up the stem and to the leaves. 2. The petiole of the leaf takes the water from the xylem in the stem to the leaf veins, which distribute it throughout the leaf. C. Leaves lose water by transpiration. 1. Transpiration occurs through tiny stomata on leaves. 2. Transpiration creates somewhat of an upward pull that assists the xylem in moving water and nutrients. D. Manufactured food is conducted from the leaves through the stems to the roots in phloem tissue.

Teacher Directions	Content Outline and/or Procedures
	1. Phloem is the tissue that conducts sugars, proteins, hormones, dissolved materials, and salts from leaves to other parts of a plant. 2. The structure is observed as elongated sieve-type cells that form tube structures in stems.
REVIEW/SUMMARY	Focus the review and summary of the lesson on the student learning objectives. Have students explain the content associated with each objective. Use specimens of plant materials for students to use in demonstrating their knowledge of the objectives. Use student responses as the basis for reteaching. Complete Examining Plant Structures and Functions worksheet and/or have students complete questions at the end of the chapters in the text.
APPLICATION	Complete LS: 06.01.PL Osmotic Turgescence (Pressure)

LS: 06.01.PL **Teacher Instructions**

Osmotic Turgescence (Pressure)

Interest Approach: ***(Present as follows.)***

Bring to class two sets of bean seeds. One of the sets should be soaked in water for approximately four hours prior to class. As the students to compare the two sets of seeds. Ask them why the seeds that had been soaked are larger.

Agriscience Applications: ***(Discuss.)***

When cells in growing tissues split and enlarge as water and nutrients are absorbed and used to make new cellular materials, a tremendous force is produced. This force is called osmotic turgescence. The strength of the force depends upon characteristics of the seed. Hydraulic pressure causes a stretching effect on the cell walls, making cell enlargement (growth) possible.

Plant cells are osmotic systems. The concentration of water is less inside the cell than outside. This osmotic process generates the cell's internal hydraulic pressure. As water enters the cell, its volume and hydraulic pressure increase.

Research Problem: ***(Present and discuss.)***

How much pressure is exerted by a seed as it takes up water for germination?

Purpose: ***(Present to class and discuss.)***

The purpose of this experiment is to observe the pressure exerted by germinating seeds.

Materials: ***(Give to students.)***

lima bean seeds (or other large beans)
dry, clean sand
pint jar with lid
masking tape
box or pan
pen or pencil

Procedures: ***(Give a copy to students and have them conduct the experiment.)***
(4 students per group)

Place an equal amount of beans and sand in a jar. Shake the jar to mix the beans and sand completely. Push the sand in tightly. Fill the jar to the top with sand.
Wet the sand, but do not put enough water into the jar to flood it.
Screw the lid on tightly
Label each jar by putting your name on a piece of masking tape on the lid of the jar.

Place the jar on a large pan or box in an area away from students. (This contains the mess of broken jars and aids in clean up afterwards.)
Observe what happens to the jar after a few hours. Record observations.

Data Summary: ***(Give sample data table to students and lead a discussion on how to summarize the data from other parts of the experiment.)***

Observations should be taken of the experiment at regular intervals. Have students complete a simple data summary table stating their observations. Be sure student observations are written in complete sentences and with good sentence structure.

Sample Data Summary Table

Time	Observation

Conclusions: ***(Lead a discussion of these and other conclusions.)***
1. Expanding seeds create enough pressure to break glass jars.

Discussion: ***(Use a supervised study session or whole class discussion to answer the following questions.)***

1 What were the most difficult aspects of conducting this experiment?
2. Did the experimental procedures produce the desired results? (Were you able to observe the pressure exerted by germinating seeds?)
3. What would you do differently in conducting this experiment a second time?
4. Why did some jars break more quickly than others?
5. Why did some jars not break at all?
6. What was the purpose of the sand in the experiment?

Further Investigation: ***(Lead a discussion of these and other ideas.)***

1 Compare different types of seeds.
2 Vary the amount of sand and seed placed in each jar.
3 Vary the temperature or light received by the jar to see if they have an effect on water uptake by the seed.

LS: 06.01.PL **Student Handout**

Osmotic Turgescence (Pressure)

Purpose:

The purpose of this experiment is to observe the pressure exerted by germinating seeds.

Research Problem:

How much pressure is exerted by a seed as it takes up water for germination?

Your hypothesis is:

Materials:

lima bean seeds (or other large beans)
dry, clean sand
pint jar with lid
masking tape
box or pan
pen or pencil

Procedures:

Place an equal amount of beans and sand in a jar. Shake the jar to mix the beans and sand completely. Push the sand in tightly. Fill the jar to the top with sand.
Wet the sand, but do not put enough water into the jar to flood it.
Screw the lid on tightly
Label each jar by putting your name on a piece of masking tape on the lid of the jar.
Place the jar on a large pan or box.
Observe what happens to the jar after a few hours. Record your observations.

Agriscience Applications:

When cells in growing tissues split and enlarge as water and nutrients are absorbed and used to make new cellular materials, a tremendous force is produced. This force is called osmotic turgescence. The strength of the force depends upon characteristics of the seed. Hydraulic pressure causes a stretching effect on the cell walls, making cell enlargement (growth) possible.

Plant cells are osmotic systems. The concentration of water is less inside the cell than outside. This osmotic process generates the cell's internal hydraulic pressure. As water enters the cell, its volume and hydraulic pressure increase.

Data Summary:

Data Summary Table

Time	Observation

Course: Agriscience Foundations I

Lesson: Determining the Importance of Photosynthesis and Respiration (06.02.PL)

Objectives:

1. Explain photosynthesis and its importance.
2. Write the chemical equation for photosynthesis and explain it.
3. Explain how light and dark reactions differ.
4. Define respiration and explain why it is important.
5. List four factors that affect the rate of respiration.
6. Explain the importance of transpiration to plants.

Student Performance Standards Addressed:

06.02: Describe the processes of plant growth including photosynthesis, respiration, and nutrient uptake.

Equipment, Supplies, References, and Other Resources:

References:

- Cooper, Elmer L. *Agriscience Fundamentals and Applications*, Third Edition. Albany, New York: Delmar Publishers, Inc., 2004.
- Lee, Jasper S. and Diana L. Turner. *AgriScience,* Third Edition. Danville, Illinois: Interstate Publishers, Inc., 2003.

Handouts:

- LS: 06.02.PL Transpiration in Plants Student Handout

Video:

- Teaching Demonstration

Computer and video projection equipment:

- PowerPoint presentation or Overhead projector
  - TM: 06.02.A Energy Flow
  - TM: 06.02.B Photosynthesis Equation
  - TM: 06.02.C Two Major Phases of Photosynthesis
  - TM: 06.02.D Comparison of Photosynthesis and Respiration
  - TM: 06.02.E Factors Affecting the Rate of Respiration
  - TM: 06.02.F Transpiration and Gas Exchange in Leaves
  - TM: 06.02.G Factors Affecting the Rate of Transpiration

Equipment & Supplies:

- See materials list on lab sheet
- Audio recorder
- Audio tapes

Teacher Directions	Content Outline and/or Procedures
REVIEW	***Push "record" on audio recorder*** Quickly review the objectives of Lesson 06.01.PL Examining Plant Structures and Functions.
INTEREST APPROACH	Start the lesson by shutting off the lights in the classroom. Ask the students if they could survive and continue to make energy if they were kept in the dark. Ask students what effect complete darkness would have on other mammals. Now ask the students what effect complete darkness would have on plants.
OBJECTIVES	
1. *Explain photosynthesis and its importance.* TM: 06.02.A Energy Flow TM: 06.02.C Two Major Phases of Photosynthesis TM: 06.02.B Photosynthesis Equation	I. Photosynthesis is the manufacture of food by plant cells. A. Sugar is the major product of photosynthesis and provides energy for the plant. B. There are two phases to the photosynthesis process. 1. Energy gathering—Plant leaves soak up sunlight. 2. Sugar making—Plants convert energy from sunlight into stored chemical energy. a. Chemical energy rearranges carbon dioxide in the plant in the presence of chlorophyll to form sugar. b. Glucose, a simple sugar, is formed. C. Photosynthesis is the most important reaction on earth. All life forms are dependent on the reaction. 1. Occurs in the chloroplasts 2. CO_2 + light + chlorophyll + H_2O _ $C_6H_{12}O_6$ (glucose) + H_2O + O_2 D. In order for photosynthesis to occur, several things must be present. 1. Chlorophyll—green colored substance in plants. 2. Light—Leaves absorb necessary energy from the sun's rays or artificial light.

Teacher Directions	Content Outline and/or Procedures
	3. Carbon Dioxide—Enters the plant through structure called stomata in the leaves. Carbon dioxide is split during photosynthesis. 4. Water—Water is also split during photosynthesis.
2. *Write the chemical equation for photosynthesis and explain it.* TM: 06.02.B Photosynthesis Equation	II. Photosynthesis is a series of chemical reactions that yields sugars, water, and oxygen. A. The chemical equation of photosynthesis can be written in words: Six molecules of carbon dioxide plus twelve molecules of water in combination with a healthy plant and some form of light energy, to make one molecule of sugar plus six molecules of water and six molecules of oxygen. B. The products of photosynthesis include carbohydrates in the form of sugars and starches as well as water and oxygen.
3. *Explain how light and dark reactions differ.*	III. Photosynthesis is a series of complex reactions that have been divided into two major phases. These two major phases have been named the light and dark reactions. A. Light Reactions— 1. The light reactions are also known as light dependent reactions. Light allows energy to be released in the form of ATP which can be used by the plant in the splitting of water and the release of oxygen. 2. The pigments in chloroplasts absorb light energy to form NADPH and ATP to be used in the breakdown of CO2 in the dark reactions. B. Dark Reaction— 1. Also known as light independent reactions. 2. A chemical known as RuBP (rubilose biphosphate) absorbs carbon. Carbon dioxide and RuBP join together and go through a process called the Calvin cycle. The Calvin cycle reduces carbon dioxide to manufacture carbohydrates. The NADPH and ATP synthesis from the light reactions provide the energy needed to power the Calvin cycle. 3. As a result of the Calvin cycle, one molecule of glucose is formed.
4. *Define respiration and*	IV. ***Respiration*** is the process by which an organism

Teacher Directions	Content Outline and/or Procedures
explain why it is important. TM: 06.02.D Comparison of Photosynthesis and Respiration	provides its cells with oxygen so energy can be released from digested food. Respiration takes place in all living cells at all times. A. ***Mitochondria*** are energy processing factories for plants. Respiration takes place in the mitochondria of all cells. B. Respiration yields the opposite results as photosynthesis. The process of photosynthesis absorbs energy, consumes carbon dioxide and releases oxygen. Respiration uses energy, consumes oxygen and releases carbon dioxide.
5. *List four factors that affect the rate of respiration.* TM: 06.02.E Factors Affecting the Rate of Respiration	V. Temperature, oxygen, soil conditions, and light can affect the rate of respiration. A. Temperature—There is a direct relationship between respiration and temperature, as the temperature increases so does the rate of respiration. B. Oxygen—Oxygen is required for respiration to take place. As oxygen levels decrease so does the rate of respiration. C. Soil conditions—Soil containing large quantities of water cause the rate of respiration to decrease because of the lack of oxygen. D. Light—The amount of energy produced by photosynthesis in low light conditions is reduced. Therefore the amount of energy available to conduct respiration is lower.
6. *Explain the importance of transpiration in plants.* TM: 06.02.F Transpiration and Gas Exchange in Leaves	VI. ***Transpiration*** in plants is the loss of water by evaporation through structures called stomata. ***Stomata*** are pores or openings in the plant that allow for the exchange of water and other substances. Transpiration in plants is similar to perspiration in humans. A. Water molecules and transpiration together form a force that is essential for water movement through plants. 1. As water evaporates through the stomata of plant, it creates a pull that aids in the absorption of water by the roots. (An analogy of using a straw to drink will help students to visualize this process.) 2. Transpiration is a vital link in the hydrologic cycle. Ninety-nine percent of all water taken in by the plant is lost to transpiration. Therefore, transpiration contributes

Teacher Directions	Content Outline and/or Procedures
TM: 06.02.G Factors Affecting the Rate of Transpiration	significantly to the generation of rainfall. B. Factors affecting the rate of transpiration include: 1. Wind speed—the relationship between wind speed and transpiration is a direct relationship. 2. Temperature—as temperature increases so does the rate of transpiration because the plant uses transpiration as a mechanism to cool itself. Once again there is a direct relationship between temperature and transpiration. 3. Humidity—Humidity influences the rate of transpiration because if the air is already saturated with water vapor, there will be a decrease in the rate of evaporation. 4. Drought—If the plant is experiencing drought conditions it will close the stomata to prevent needed water from escaping. When the plant's stomata are closed transpiration does not take place.
REVIEW/SUMMARY	Focus the review and summary of the lesson around the student learning objectives. Call on students to explain the content associated with each objective. Questions at the end of each chapter in the recommended textbooks may also be used in the review/summary. Complete the Determining the Importance of Photosynthesis and Respiration worksheet.
APPLICATION	Complete LS: 06.02.PL Transpiration in Plants

LS: 06.02.PL **Teacher Instructions**

Transpiration in Plants

Interest Approach: ***(Present as follows)***

Ask three to five students to volunteer participate in a race. Give each volunteer a penny, a pipette, and cup of water. The rules of the competition are simple, the person who can put the largest numbers of water drops on the top of the penny without getting the table wet wins. You may also ask for another set of students to volunteer to help count the number of drops on each students penny. After the "race" is over, ask the competitors to describe to the rest of the class what happened. Why were you able to get so many drops on the penny? Describe the properties of adhesion and cohesion. Relate to transpiration in plants.

Agriscience Applications: ***(Discuss)***

Transpiration is the loss of water through plant leaves. Over 90% of all water absorbed by the plant is lost through this process. This water loss occurs through the stomata, which are located on the underside of plant leaves. Some plants also have stomata on the upper side of the leaves. The stomata are pores that open and close under certain conditions. In addition to allowing water vapor to escape, the stomata also allow the inward movement of atmospheric carbon dioxide which is used in photosynthesis.

Osmosis and diffusion are the primary means by which plants absorb water from the soil and release water through transpiration. Diffusion is the movement of molecules (water) from a region of higher concentration to a region of lower concentration. Transpiration water losses occur by diffusion. Osmosis is the diffusion of water through a differentially permeable membrane. Water enters the cell by osmosis then travels across several membranes until it moves into the xylem. It is then transported to the leaves where much of the water is diffused through the stomata.

The upward movement of water from the roots to the leaves is known as the transpiration stream. As water is lost from the outer tissues of the leaf, water moves in from interior tissue. Differences in osmotic pressure between cell layers causes this "suction" of water from the roots to the leaves. This process is facilitated by the cohesion properties of water. Cohesion is the attraction between like molecules (water to water). Adhesion is the attraction between unlike molecules (water to plant tissue).

Light, carbon dioxide concentrations, and water content in plant tissue affect the stomata. Air movement and humidity affect the opening and closing the stomata. Changes in turgor pressure of the guard cells cause the stomatal pores to open and close. When the stomata are closed, water loss is reduced. However, if the stomata are closed, carbon dioxide cannot enter the plant. Thus prohibiting photosynthesis from occurring.

Maintaining adequate soil moisture is a critical management practice in plant growth for both indoor and outdoor growing conditions. For greenhouse crops, watering is probably the most time-consuming task required in growing a given crop. Fortunately, the high labor costs of maintaining proper moisture levels is somewhat offset by the relatively low cost of water as an input for greenhouse crops.

In outdoor growing conditions, including vegetables, turf, and field crops, soil moisture fluctuates much more and reaches more extreme levels than in more controlled, indoor environments. Thus, maintaining adequate soil moisture levels in outdoor conditions is much more of a challenge, due to weather factors beyond the grower's control. Soil moisture levels are increased either by natural means (rainfall) or artificially via irrigation. Moisture losses occur primarily through the evaporation of water from the upper soil layers through the loss of water through leaf surfaces and other plant parts (transpiration). The rate of water loss as a result of transpiration is primarily dependent upon weather (i.e., temperature and humidity). Thus, growers must seasonally adjust their crop schedules according to the water intake and loss responses of the plants being grown.

Research Problems: ***(Present and discuss)***

1. What effect does leaf size and number have on plant transpiration rate?
2. What effect does air movement have on plant transpiration rate?

Purpose: ***(Present to class and discuss)***

The purpose of this experiment is to observe the general rate of transpiration in plants and to examine the effects of wind on transpiration rate. Through this lab, students will be able to:

1. describe the biological process of transpiration in plants;
2. identify the factors that affect transpiration and explain why and how these effects are realized;
3. measure transpiration rates in given test plants; and
4. explain the relationship between transpiration and soil moisture management practices on plant growth.

Materials: ***(Give to students)***

- Four 50-milliliter graduated cylinders
- Modeling clay
- Cooking oil
- Cuttings from a large-leafed, herbaceous plant
- Water
- Electric fan
- Graph paper

Procedures:
(Give a copy to students and have them conduct the experiment.)
(4 students per group)

1. Take four stem cuttings (8 to 10 inches long) from stock plants. Choose stem cuttings with leaves of relatively equal size. Remove all but one leaf from two of the cuttings. Leave three or four leaves on each of the other two cuttings.
2. Add water to the four graduated cylinders.
3. Place the stem of the cuttings so they extend well below the water line in the graduated cylinders.
4. Pour 2 milliliters of cooking oil on top of the water in the graduated cylinder to prevent evaporation losses.
5. Gently pack modeling clay around the stem at the cylinder opening to provide support for the plant. Be careful not to crush the stem. Try to establish initial water line near 40 milliliters.
6. Record the water level in each cylinder.
7. Place all four cylinders under the same environmental conditions (temperature, light, etc.) with one exception. Two of the cylinders (one with a single leaf and one with multiple leaves) should be placed in front of a low-speed fan.
8. Record the water level in each cylinder on a regular basis.
9. Summarize the data. Graph the results ***(Be sure students have properly identified the independent and dependent variables and that the graphs are labeled appropriately.)***

Data Summary: ***(Give sample data table to students and lead a discussion on how to summarize the data obtained from other parts of the experiment.)***

Observations should be taken of the experiment at regular intervals. Have students complete the simple data summary table. Students should graph the water loss the occurred during the time of the experiment.

Treatment	Initial Reading	End Day 1		Beginning Day 2		End of Day 2	
		Reading	Net Change	Reading	Net Change	Reading	Net Change
1 leaf, no fan							
3-4 leaves, no fan							
1 leaf, fan							
3-4 leaves, fan							

Conclusions: ***(Lead a discussion of these and other conclusions.)***

1. Moisture is lost through the leaves.
2. The greater the number of leaves (leaf surface area), the greater the loss from transpiration.
3. Increased airflow (up to a certain speed) will increase the rate of transpiration.

Discussion:

(Use a supervised study session or whole class discussion to answer the following questions.)

1. What were the most difficult aspects of conducting this experiment?
2. Did the experimental procedures allow you to answer the research question?
3. What would you do differently in conducting this experiment a second time?
4. What effect would transpiration have on the way you would manage a greenhouse?
5. What plants would be more susceptible to greater losses of moisture due to transpiration?
6. Why were herbaceous plants selected for this experiment?
7. Why does air movement tend to increase the rate of transpiration?
8. What would happen if transpiration rate exceeded the rate at which the plant could replenish the water in its tissues?
9. At what point does an increase in air speed decrease transpiration? Why?
10. What is the relationship between rate of transpiration and leaf surface area?
11. What causes water to be pulled upward into the leaf stems?

Further Investigation:

(Lead a discussion of these and other ideas.)

1. Examine the effects of additional environmental factors such as light intensity, temperature, and humidity on the rate of transpiration in plants.
2. Examine the rate of transpiration in plants that are growing under various degrees of soil moisture.

LS: 06.02.PL **Student Handout**

Transcription in Plants

Purpose of this Lab:

The purpose of this experiment is to observe the general rate of transpiration in plants and to examine the effects of wind on transpiration rate. Through this lab, students will be able to:

1. describe the biological process of transpiration in plants;
2. identify the factors that affect transpiration and explain why and how these effects are realized;
3. measure transpiration rates in given test plants; and
4. explain the relationship between transpiration and soil moisture management practices on plant growth.

Research Problems:

1. What effect does leaf size and number have on plant transpiration rate?
2. What effect does air movement have on plant transpiration rate?

Your hypothesis is:

Materials:

- Four 50-milliliter graduated cylinders
- Modeling clay
- Cooking oil
- Cuttings from a large-leafed, herbaceous plant
- Water
- Electric fan
- Graph paper

Procedures:

1. Take four stem cuttings (8 to 10 inches long) from stock plants. Choose stem cuttings with leaves of relatively equal size. Remove all but one leaf from two of the cuttings. Leave three or four leaves on each of the other two cuttings.
2. Add water to the four graduated cylinders.
3. Place the stem of the cuttings so they extend well below the water line in the graduated cylinders.

4. Pour 2 milliliters of cooking oil on top of the water in the graduated cylinder to prevent evaporation losses.
5. Gently pack modeling clay around the stem at the cylinder opening to provide support for the plant. Be careful not to crush the stem. Try to establish initial water line near 40 milliliters.
6. Record the water level in each cylinder.
7. Place all four cylinders under the same environmental conditions (temperature, light, etc.) with one exception. Two of the cylinders (one with a single leaf and one with multiple leaves) should be placed in front of a low-speed fan.
8. Record the water level in each cylinder on a regular basis.
9. Summarize the data. Graph the results ***(Be sure you have properly identified the independent and dependent variables and that the graphs are labeled appropriately.)***

Agriscience Applications:

Transpiration is the loss of water through plant leaves. Over 90% of all water absorbed by the plant is lost through this process. This water loss occurs through the stomata, which are located on the underside of plant leaves. Some plants also have stomata on the upper side of the leaves. The stomata are pores that open and close under certain conditions. In addition to allowing water vapor to escape, the stomata also allow the inward movement of atmospheric carbon dioxide which is used in photosynthesis.

Osmosis and diffusion are the primary means by which plants absorb water from the soil and release water through transpiration. Diffusion is the movement of molecules (water) from a region of higher concentration to a region of lower concentration. Transpiration water losses occur by diffusion. Osmosis is the diffusion of water through a differentially permeable membrane. Water enters the cell by osmosis then travels across several membranes until it moves into the xylem. It is then transported to the leaves where much of the water is diffused through the stomata.

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In outdoor growing conditions, including vegetables, turf, and field crops, soil moisture fluctuates much more and reaches more extreme levels than in more controlled, indoor environments. Thus, maintaining adequate soil moisture levels in outdoor conditions is much more of a challenge, due to weather factors beyond the grower's control. Soil moisture levels are increased either by natural means (rainfall) or artificially via irrigation. Moisture losses occur primarily through the evaporation of water from the upper soil layers through the loss of water through leaf surfaces and other plant parts (transpiration). The rate of water loss as a result of transpiration is primarily dependent upon weather (i.e., temperature and humidity). Thus, growers must seasonally adjust their crop schedules according to the water intake and loss responses of the plants being grown.

Data Summary

Treatment	Initial Reading	End Day 1		Beginning Day 2		End of Day 2	
		Reading	Net Change	Reading	Net Change	Reading	Net Change
1 leaf, no fan							
3-4 leaves, no fan							
1 leaf, fan							
3-4 leaves, fan							

Course: Agriscience Foundations I

Lesson: Propagating Plants Sexually (06.03.PL)

Objectives:

1. Explain sexual reproduction of plants and its importance in plant survival.
2. Explain how pollination occurs and describe the different types of pollination.
3. Explain fertilization in flowering plants.
4. Explain the structures and formation of seeds.
5. Describe the conditions for seed germination.
6. Compare and contrast indoor and outdoor growing conditions.

Student Performance Standards Addressed:

06.03: Propagate plants through sexual and asexual means.

Equipment, Supplies, References, and Other Resources:

References:

- Cooper, Elmer L. *Agriscience Fundamentals and Applications*, Third Edition. Albany, New York: Delmar Publishers, Inc., 2004.
- Lee, Jasper S. and Diana L. Turner. *AgriScience,* Third Edition. Danville, Illinois: Interstate Publishers, Inc., 2003.

Handouts:

- LS: 06.03.A.PL Environmental Factors Affecting Germination Student Handout
- LS: 06.03.B.PL Salinity and Seed Germination Student Handout

Video:

- Teaching Demonstration

Computer and video projection equipment:

- PowerPoint presentation or overhead projector
  - TM: 06.03a.A Pollination of a Flower
  - TM: 06.03a.B Fertilization of a Flower
  - TM: 06.03a.C Parts of a Bean Seed and a Corn Seed
  - TM: 06.03a.D Environmental Factors Necessary for Germination

Equipment & Supplies:

- Examples of perfect flowers (Interest Approach)
- See materials list on lab sheet
- Audio recorder
- Audio tapes

Teacher Directions	Content Outline and/or Procedures
REVIEW	***Push "record" on audio recorder*** Quickly review the objectives of Lesson 06.02.PL Determining the Importance of Photosynthesis and Respiration.
INTEREST APPROACH	Bring a couple of samples of perfect flowers, such as from a Hibiscus or a Lily plant, to class. Use them to show the students the various parts of a flower. Dissect the flower and demonstrate to students how the pollen gets from the anther to the stigma and then grows a pollen tube down through the style to fertilize the egg. Students should be able to see how the various parts of the flower interact for pollination to occur.
OBJECTIVES	
1. Explain sexual reproduction of plants and its importance in plant survival.	I. Sexual reproduction involves flowers, fruits, and seeds. A. In sexual reproduction, sperm carried in the pollen from the male flower fuses with the egg in the female part of the flower. Both contribute to the genetic makeup of the new plant. B. Each time sexual reproduction occurs, there is a recombining of genetic material. As a result, some changes will occur. Some may be beneficial and some may not. As conditions of the environment change over time, the beneficial changes in plant genetics will allow the plant to survive. As plants continue to reproduce, they pass genes onto their offspring, which enables them to survive.
2. Explain how pollination occurs and describe the different types of pollination. TM: 06.03a.A Pollination of a Flower	II. Pollination is the transfer of pollen from the male to the female part of a plant. A. Pollination occurs in many different ways: 1. Birds, insects, bats, and other animals are attracted to colorful, scented flowers. As they visit various flowers for food, they unintentionally pick up pollen and carry it from flower to flower. 2. Wind moves pollen from one flower to another. Plants that rely on wind generally do not produce colorful flowers with scents or nectar. B. Pollination of plants may occur in one of two ways:

Teacher Directions	Content Outline and/or Procedures
	1. Self-pollination occurs when pollen from a plant pollinates a flower on the same plant. 2. Cross-pollination occurs when pollen from a plant pollinates a flower on a different plant. C. Once pollen lands on the stigma, it grows a pollen tube down the style to the ovary. The cell within the grain of pollen divides to form two sperm nuclei, which travel down the pollen tube to the embryo sac, fertilizing the egg.
3. Explain fertilization in flowering plants. TM: 06.03a.B Fertilization of a Flower	III. Fertilization is necessary in flowering plants in order for the seed to develop. A. Fertilization in flowering plants is different from fertilization in any other living organism. In plants, both sperm nuclei in the pollen grain are involved in fertilization, resulting in a double fertilization. 1. The first fertilization occurs when one sperm fuses with the egg, resulting in a zygote. The resulting seed contains genetic information from both the male and female part of the flower. 2. The second fertilization occurs when the second sperm nucleus fuses with the two nuclei in the embryo sac. This will develop into the endosperm. The ovule of the flower will become the seed. B. When fertilization occurs and the parents are genetically different, the resulting offspring is said to be a hybrid. The advantage of hybrids is that the best traits of each parent, such as more vigorous growth, insect and disease resistance, or uniformity, may be expressed in the offspring. C. Genetic information is stored in every cell of a plant in long molecular chains made of Deoxyribonucleic acid (DNA). Segments of DNA, called genes, establish the code for life processes and the appearance of a plant. The genes are arranged in a set of chromosomes. Normal cells contain a double set of chromosomes and are said to be diploid. Reproductive cells, sperm and egg cells, have a single set of chromosomes and are said to be haploid. When fertilization occurs, the single sets of chromosomes are combined into the double set, one from each parent, resulting in traits from each parent being passed on to the offspring.

Teacher Directions	Content Outline and/or Procedures
4. Explain the structures and formation of seeds. TM: 06.03a.C Parts of a Bean Seed and a Corn Seed.	IV. The function of the seed is to grow and develop into a mature plant that will produce more seeds. A. Seeds of flowering plants have several parts. 1. The seed coat is a protective shell surrounding the embryo and endosperm. It protects the seed from drying and from physical injury. The seed coat helps in determining when conditions for germination or the beginning of growth are right. 2. The embryo is a little plant that eventually grows and develops into the mature plant. It remains dormant within the seed. It has a stem, root, and one or two seed leaves called cotyledons. Monocot embryos have one seed leaf and dicot embryos have two seed leaves. 3. The endosperm is the food storage tissue in the seed, particularly in monocots. Dicots store their food in the two cotyledons. The food storage is necessary for the young seedling until it is able to manufacture its own food. B. After fertilization, the ovary wall enlarges and forms the fruit. The fruit may be fleshy or dry. 1. Fleshy fruit prevents the seeds from drying until they are mature. They also serve to help disperse the seeds. Animals are attracted to fruit, eat it with the seeds, and disperse or disseminate the seeds somewhere away from the parent plant. Examples of fleshy fruit include tomatoes, apples, pears, etc. 2. Dry fruit is found on plants such as the dandelion and maple trees. It does not depend on animals for dissemination, but may depend on wind or other methods of dissemination.
5. Describe the conditions for seed germination. TM: 06.03a.D Environmental Factors Necessary for Germination	V. Seeds are designed to wait for favorable conditions to begin growth. They may lay dormant for many years before conditions allow them to begin to grow. A. Several environmental factors play key roles in seed germination. 1. Moisture or water is necessary for germination. 2. Air, particularly oxygen, is required for germination.

Teacher Directions	Content Outline and/or Procedures
	3. Warm temperatures, between 40 and 104 degrees F, are necessary for germination. 4. Some plants require light or total darkness for germination. B. Stratification is when the seed must go through a period of cold temperatures before it will germinate. C. Scarification is the breaking down of the seed coat. Some seeds have such a hard, thick seed coat that they prevent the absorption of water to enable germination to occur. D. The germination process begins with the absorption of water. The seed swells and the embryo changes from a dormant state to an actively growing plant. The embryo draws energy from starches stored in the endosperm or cotyledons. The embryo's root emerges from the seed and develops into the primary root. Then, the stem of the embryo sprouts upward. E. The quality of seed used is very important in production agriculture. Viable, or live, seed is important to ensure a high percentage of seed germination. Seed companies test seed to determine its germination percentage, which must be printed on the seed bag. Proper humidity and temperature during storage of the seeds help maintain seed viability. 5. High salt concentrations in the soil can have adverse effects on plant growth. A. Soil salinity is most severe in arid, irrigated areas around the world. Salinity may affect as much as 30% of all irrigated land in the U.S., primarily in the southwestern part of the country. B. In field conditions dissolved salts are usually applied in the irrigation water. Enough salt may accumulate in a few years to reduce the productivity of the soil. Standard practice in irrigation is to add enough water to permit some drainage to help remove salt buildup in the soil. Artificial drainage is a major investment. Research now underway is aimed at determining optimal amounts of irrigated water to apply, and developing simple methods of measuring soil salinity concentrations in the soil.

Teacher Directions	Content Outline and/or Procedures
	C. Salt buildup may also be a problem in greenhouse crops and indoor plants if drainage outlets are not provided in the growing container. Inadequate watering, even with well designed containers, can lead to salt buildup in the growing medium and eventual death of the plant.
6. Compare and contrast indoor and outdoor growing conditions.	VI. The grower has control over the quality and condition of seed, planting procedure, and weed competition, environmental conditions cannot be controlled in outdoor settings. The grower must be able to correctly interpret planting conditions and adjust timing and planting procedures accordingly. A. A major advantage of growing plants in greenhouses is that critical environmental conditions of moisture, temperature, oxygen and light can accurately be controlled. Control and/or correct adaptation to environmental conditions enhance overall seed germination and seedling establishment. Germination percentage affects plant population, which in turn affects profit potential of a given crop. B. In outdoor settings soil and seedbed conditions have a direct influence on moisture and oxygen availability for seed germination in vegetable, agronomic and horticulture crops. In addition, all plants have soil temperature ranges that will promote acceptable germination rates. Thus, growers must know the temperature ranges for their crops and time their plantings accordingly in order to ensure good germination and seedling establishment.
REVIEW/SUMMARY	Use the student learning objectives to summarize the lesson. Have students explain the content associated with each objective. Student responses can be used in determining which objectives need to be reviewed or taught from a different perspective. Questions at the end of chapters of textbooks covering this material may also be used in the review/summary. Complete Propagating Plants Sexually Worksheet.
APPLICATION	Complete LS: 06.03.A.PL Environmental Factors Affecting Germination and LS: 06.03.B.PL Salinity and Seed Germination.

LS: 06.03.A.PL **Teacher Instructions**

Environmental Factors Affecting Germination

Interest Approach: ***(Present as follows.)***

Bring to class samples of a variety of seeds, including lettuce, marigold, grass, wheat and others. Ask students what conditions would be best for planting these seeds. Do all of these types of seed need the same conditions for optimal germination? If not, what are the unique requirements of each? Have one or more students plant some seeds in a flat or pot and then ask students to describe the ideal germination conditions for that seed type. Challenge their procedures (to maintain uncertainty in their minds about whether they have enough knowledge and skill to perform this task correctly).

Agriscience Applications: ***(Discuss.)***

While the grower has control over the quality and condition of seed, planting procedure, and weed competition, environmental conditions cannot be controlled in outdoor settings. The grower must be able to correctly interpret planting conditions and adjust timing and planting procedures accordingly. A major advantage of growing plants in greenhouses is that critical environmental conditions of moisture, temperature, oxygen and light can accurately be controlled. Control and/or correct adaptation to environmental conditions enhance overall seed germination and seedling establishment. Germination percentage affects plant population, which in turn affects profit potential of a given crop.

In outdoor settings soil and seedbed conditions have a direct influence on moisture and oxygen availability for seed germination in vegetable, agronomic and horticulture crops. In addition, all plants have soil temperature ranges that will promote acceptable germination rates. Thus, growers must know the temperature ranges for their crops and time their plantings accordingly in order to ensure good germination and seedling establishment.

Research Problem: **(*Present and discuss.)***

How do light, oxygen, temperature and moisture affect seed germination?

Purpose: ***(Present to class and discuss.)***

The purpose of this set of experiments is to examine the effects of the environmental conditions of light, oxygen, temperature, and moisture on seed germination. Optimal environmental conditions for selected plants will be generally determined. Through these experiments, students will be able to :

1. explain the effects of light, water, temperature, and oxygen on seed germination and why each of these elements is essential for germination; and

2. explain and/or develop recommended practices for planting selected vegetable, agronomic, and horticultural crops in terms of the germination process.

Materials: ***(Give to students.)***

- lettuce or grass seeds
- bean seeds
- quart plastic bags (Ziplock)
- paper towels
- aluminum foil
- steel wool
- 2 jars with air-tight lids (pint or quart size)
- incubator or similar source for heat
- refrigerator
- eight 6 inch pots with potting soil or other soil mixture
- water
- gravel
- graph paper

Procedures: ***(Give a copy to students and have them conduct the experiment.)***
(4 students per group)

Effects of light on germination:

1. Divide 75 lettuce or grass seeds into three groups of 25.
2. Wet six paper towels and fold two at a time so that they will fit into the plastic bags. Place one set of folded towels in each of six plastic bags.
3. Place 25 lettuce/grass seeds on top of the paper towels in each of three plastic bags.
4. Wrap two of the lettuce/grass bags in aluminum foil to exclude light.
5. Place all bags in the same place under moderate conditions of light and room temperature.
6. After one day, unwrap the foil from one group of seeds and expose to light for one hour. Then re-cover with foil and label as to light exposure conditions.
7. Count the number of seeds that germinate after two and four days in each of the three bags. Record data and calculate the rate of germination. Graph results ***(Be sure students have properly identified the independent and dependent variables and that the graphs are labeled appropriately.)***

Effects of oxygen on germination:

1. Soak 20 bean seeds in water for 12 hours.
2. Obtain two jars with tight-fitting lids and line the sides with paper towels.
3. Loosely stuff paper towels into one jar to keep the lining pressed to the sides.
4. Loosely stuff paper towels and steel wool pads into the center of the other jar.
5. Evenly space ten bean seeds between the paper towels and wall of each jar.
6. Wet the contents of both jars leaving approximately two to three cm. of water in the bottom of each jar.

7. Tightly seal each jar.
8. Observe the bean seeds daily for seven to ten days.
9. Observe the steel wool after seven to ten days and record your observations. Graph results ***(Be sure students have properly identified the independent and dependent variables and that the graphs are labeled appropriately.)***

Effects of temperature on germination:

1. Divide 75 bean seeds into three groups of 25.
2. Evenly space 25 seeds on top to two layers of moistened paper towels. Cover the seeds with two more layers of moistened paper towels.
3. Fold over the edges of the towels and roll up the towels and enclosed seeds into a tube (called a rag doll). Secure each end with a rubber band. Repeat this procedure until two more rag dolls are made.
4. Label each plastic bag with where the seed will be placed: cold, warm, control (room temperature). Put one rag doll in each bag and seal.
5. Place the bags in the assigned environment, positioning the rag dolls in an upright position:
    - *Warm environment*- Use an incubator or heat source which will keep the seeds at approximately 85-90° F.
    - *Control*- Room temperature 68-76° F.
    - *Cold environment*- Place seeds in the refrigerator (35-40° F).
6. Record the number of seeds germinated at days 3, 5, and 7 for each treatment group and calculate the final germination percentage at day seven. Graph results ***(Be sure students have properly identified the independent and dependent variables and that the graphs are labeled appropriately.)***
7. Combine individual student data to obtain class average.

Effects of moisture on germination:

1. Divide 80 bean seeds into equal groups of 10. Place a small amount of gravel in the bottom of eight 6-inch pots. Then fill with potting soil or another soil mixture to within one inch of the top of the pot. Slowly pour one liter of tap water into each pot and allow to drain well by tipping and shaking pot.
2. Plant ten seeds 1 cm deep in each of four pots and label. Plant ten seeds 4 cm deep in the other four pots and label accordingly.
3. Four different watering patterns will be tested for each of the two planting depths. Label one pot from each planting depth group as follows: no additional water; 80 ml on day 5; 40 ml on days 2, 4, 6, and 8; and 40 ml every day. Place pots in a sunny location, maintaining a temperature of at least 70 degrees F.
4. Add water as indicated by the treatment group for the next 9 days.
5. Record the number of seeds germinated in each pot on days 4, 7, and 10. Calculate the germination percentage. Graph results ***(Be sure students have properly identified the independent and dependent variables and that the graphs are labeled appropriately.)***

Anticipated Findings:

(Lead a discussion of these expected results before students conduct the experiments.)

Actual numbers of seeds that germinate will vary, but greater exposure to light should be accompanied by greater germination of the lettuce/grass seeds and less germination by the onion sets. Seeds in oxygen-rich environments will germinate better. Seeds stored in the warmest temperatures should germinate the quickest and yield the highest percentage of germination. Moisture and seed depth will also have optimum levels.

Data Summary: ***(Give sample data table to students and lead a discussion on how to summarize the data obtained from other parts of the experiment.)***

Observations should be taken in each of the four experiments as specified and the number of germinated seeds recorded. Have students complete simple data summary tables for each experiment. Students should graph the germination percentages in the moisture experiment by treatment group and number of days. In addition, students should observe and record the quality/healthiness of seedlings in the temperature, oxygen, and moisture experiments.

Sample Data Summary Table

Day	Cold		Room Temp.		Warm	
	#	%	#	%	#	%
3						
5						
7						

Conclusions: ***(Lead a discussion of these and other conclusions.)***

1. Some seeds need light to germinate.
2. Seeds need oxygen to germinate.
3. Warmer temperatures increase germination for most seeds.
4. Seeds need moisture to germinate.
5. Optimum levels of moisture, temperature, and planting depth exist.

Discussion:

(Use a supervised study session or whole class discussion to answer the following questions.)

1. What were the most difficult aspects of conducting this experiment?
2. Did the experimental procedures produce the desired results? (Were you able to answer your research question?)
3. What would you do differently in conducting this experiment a second time?
4. Why do some seeds need light to germinate?
5. Why is moisture needed for germination?
6. Why is good seed to soil contact needed for successful germination?
7. What happens if seeds are planted too deeply? Why?

8. Why is oxygen needed for seed germination?
9. Are viable seeds alive? Explain.
10. Why don't most seeds need light to germinate, since light is necessary for photosynthesis?
11. What happens inside a seed to cause it to germinate?
12. Why did the seeds inside the jar with steel wool germinate poorly?
13. Why do cold temperatures slow or stall germination?

Further Investigation:

(Lead a discussion of these and other ideas.)

1. Compare the impact of these environmental factors for a variety of seed types.
2. Vary the amount of light in the first experiment to determine how much light per day is optimal for seeds that require light for germination.

LS: 06.03.A.PL **Student Handout**

ENVIRONMENTAL FACTORS AFFECTING GERMINATION

Purpose and Objectives of Lab:

The purpose of this set of experiments is to examine the effects of the environmental conditions of light, oxygen, temperature, and moisture on seed germination. Optimal environmental conditions for selected plants will be generally determined. Through these experiments, students will be able to :

1. explain the effects of light, water, temperature, and oxygen on seed germination and why each of these elements is essential for germination; and
2. explain and/or develop recommended practices for planting selected vegetable, agronomic, and horticultural crops in terms of the germination process.

Research Problem:

How do light, oxygen, temperature and moisture affect seed germination?

Your hypothesis is:

Materials:

- lettuce or grass seeds
- bean seeds
- quart plastic bags (Ziplock)
- paper towels
- aluminum foil
- steel wool
- 2 jars with air-tight lids (pint or quart size)
- incubator or similar source for heat
- refrigerator
- eight 6 inch pots with potting soil or other soil mixture
- water
- gravel
- graph paper

Procedures:

Effects of light on germination:

1. Divide 75 lettuce or grass seeds into three groups of 25.
2. Wet six paper towels and fold two at a time so that they will fit into the plastic bags. Place one set of folded towels in each of six plastic bags.
3. Place 25 lettuce/grass seeds on top of the paper towels in each of three plastic bags.

4. Wrap two of the lettuce/grass bags in aluminum foil to exclude light.
5. Place all bags in the same place under moderate conditions of light and room temperature.
6. After one day, unwrap the foil from one group of seeds and expose to light for one hour. Then re-cover with foil and label as to light exposure conditions.
7. Count the number of seeds that germinate after two and four days in each of the three bags. Record data and calculate the rate of germination. Graph results ***(Be sure you have properly identified the independent and dependent variables and that the graphs are labeled appropriately.)***

Effects of oxygen on germination:

1. Soak 20 bean seeds in water for 12 hours.
2. Obtain two jars with tight-fitting lids and line the sides with paper towels.
3. Loosely stuff paper towels into one jar to keep the lining pressed to the sides.
4. Loosely stuff paper towels and steel wool pads into the center of the other jar.
5. Evenly space ten bean seeds between the paper towels and wall of each jar.
6. Wet the contents of both jars leaving approximately two to three cm. of water in the bottom of each jar.
7. Tightly seal each jar.
8. Observe the bean seeds daily for seven to ten days.
9. Observe the steel wool after seven to ten days and record your observations. Graph results ***(Be sure you have properly identified the independent and dependent variables and that the graphs are labeled appropriately.)***

Effects of temperature on germination:

1. Divide 75 bean seeds into three groups of 25.
2. Evenly space 25 seeds on top to two layers of moistened paper towels. Cover the seeds with two more layers of moistened paper towels.
3. Fold over the edges of the towels and roll up the towels and enclosed seeds into a tube (called a rag doll). Secure each end with a rubber band. Repeat this procedure until two more rag dolls are made.
4. Label each plastic bag with where the seed will be placed: cold, warm, control (room temperature). Put one rag doll in each bag and seal.
5. Place the bags in the assigned environment, positioning the rag dolls in an upright position:
    Warm environment- Use an incubator or heat source which will keep the seeds at approximately 85-90° F.
    Control- Room temperature 68-76° F.
    Cold environment- Place seeds in the refrigerator (35-40° F).
6. Record the number of seeds germinated at days 3, 5, and 7 for each treatment group and calculate the final germination percentage at day seven. Graph results ***(Be sure you have properly identified the independent and dependent variables and that the graphs are labeled appropriately.)***
7. Combine individual data to obtain class average.

Effects of moisture on germination:

1. Divide 80 bean seeds into equal groups of 10. Place a small amount of gravel in the bottom of eight 6-inch pots. Then fill with potting soil or another soil mixture to within one inch of the top of the pot. Slowly pour one liter of tap water into each pot and allow to drain well by tipping and shaking pot.
2. Plant ten seeds 1 cm deep in each of four pots and label. Plant ten seeds 4 cm deep in the other four pots and label accordingly.
3. Four different watering patterns will be tested for each of the two planting depths. Label one pot from each planting depth group as follows: no additional water; 80 ml on day 5; 40 ml on days 2, 4, 6, and 8; and 40 ml every day. Place pots in a sunny location, maintaining a temperature of at least 70 degrees F.
4. Add water as indicated by the treatment group for the next 9 days.
5. Record the number of seeds germinated in each pot on days 4, 7, and 10. Calculate the germination percentage. Graph results ***(Be sure you have properly identified the independent and dependent variables and that the graphs are labeled appropriately.)***

Agriscience Applications:

While the grower has control over the quality and condition of seed, planting procedure, and weed competition; environmental conditions cannot be controlled in outdoor settings. The grower must be able to correctly interpret planting conditions and adjust timing and planting procedures accordingly. A major advantage of growing plants in greenhouses is that critical environmental conditions of moisture, temperature, oxygen and light can accurately be controlled. Control and /or correct adaptation to environmental conditions enhance overall seed germination and seedling establishment. Germination percentage affects plant population, which in turn affects profit potential of a given crop.

In outdoor settings soil and seedbed conditions have a direct influence on moisture and oxygen availability for seed germination in vegetable, agronomic and horticulture crops. In addition, all plants have soil temperature ranges that will promote acceptable germination rates. Thus, growers must know the temperature ranges for their crops and time their plantings accordingly in order to ensure good germination and seedling establishment.

Data Summary

Effect of Light on Germination

Treatment	Germination			
	2 Days		4 Days	
	#	%	#	%
No Light				
Limited Light (1 hour)				
Constant Light				

Effects of Oxygen on Germination

Day	Bean Seed Observation
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Steel Wool Observation after 7 – 10 days

Effects of Temperature on Germination

Day	Cold		Room Temp.		Warm	
	#	%	#	%	#	%
3						
5						
7						

Effects of Moisture on Germination

Treatment	Germination											
	1 cm Deep						4 cm Deep					
	Day 4		Day 7		Day 10		Day 4		Day 7		Day 10	
	#	%	#	%	#	%	#	%	#	%	#	%
No additional water												
80 ml on day 5												
40 ml on days 2, 4, 6, and 8												
40 ml every day												

LS: 06.03.B.PL **Teacher Instructions**

Salinity and Seed Germination

Interest Approach: ***(Present as follows.)***

Ask students to identify areas in Florida, the United States and around the world where field crops are irrigated. In what geographical areas does irrigated water provide essentially the only water received by the crop during a growing season? How do irrigated water and rain water differ? Which is better for plants? Why? Steer students in the direction of salt buildup in irrigated soils. Why does this occur? What effects does it have on crops? Why? Is this also a problem with container plants? Why or why not?

As an alternative, bring a potted plant to class. Tell students you accidentally spilled some table salt onto the soil of a potted plant. Will this harm the plant? Why? Can the salt be washed out of the soil? Tie this into salt buildup in irrigated soils as described above. Continue to care for the plant in the usual way and let students observe the effects of the salt on the plant.

Agriscience Applications: ***(Discuss.)***

High salt concentrations in the soil can have adverse effects on plant growth. Although plants require certain salt constituents for growth, some soils contain such large quantities of soluble salts that crop yields are decreased. Soil salinity is most severe in arid, irrigated areas around the world. Salinity may affect as much as 30% of all irrigated land in the U.S., primarily in the southwestern part of the country. A wide variety of major agronomic and horticultural crops are grown in this region of the United States.

In field conditions dissolved salts are usually applied in the irrigation water. Enough salt may accumulate in a few years to reduce the productivity of the soil. Current standard practice in irrigation is to add enough water to permit some drainage to help remove salt buildup in the soil. Artificial drainage is a major investment. Research now underway is aimed at determining optimal amounts of irrigated water to apply, and developing simple methods of measuring soil salinity concentrations in the soil.

Salt buildup may also be a problem in greenhouse crops and indoor plants if drainage outlets are not provided in the growing container. Inadequate watering, even with well designed containers, can lead to salt buildup in the growing medium and eventual death of the plant.

Research Problem: ***(Present and discuss.)***

What are the effects of salt buildup in soils on seed germination and plant growth?

Purpose of Lab: ***(Present to class and discuss.)***

The purpose of this experiment is to determine the effects of salt accumulation in soils on seed germination and plant growth. By participating in this lab, students will be able to:

1. explain the causes of soil salinity;
2. describe the general effects of salt accumulation in soils on plant growth and development; and

3. explain why/how excessive salt concentrations in soil water have harmful effects on plants.

Materials: ***(Give to students.)***

- twelve 6" pots with drainage holes
- 20 lb. bag of potting soil
- 30 seeds each of peas, green beans, and sweet corn
- four 2-liter containers with lids or caps
- table salt
- gravel
- 50 ml beaker
- balance
- graph paper

Procedures: ***(Give a copy to students and have them conduct the experiment.)***
(4 students per group)

1. Place about 2 cm of gravel in the bottom of each of 12 pots. Then add about 9 cm of potting soil to each pot so the soil line is about 3 cm from the top of the pot.
2. Add one liter of tap water to each pot and allow to drain well by tipping and shaking.
3. Make 4 irrigation solutions by adding 36g of NaCl (table salt) to container #4, 24g to container #3, 12g to container #2, and no salt to container #1. Fill each container with 2 liters of tap water.
4. Plant 10 green bean seeds 2 cm deep in each of 4 pots. Plant 4 pots of sweet corn and 4 pots of peas in the same manner.
5. Label all pots with seed type and 1 through 4 for irrigation solution.
6. Place the pots in a sunny location and keep moist (but not wet) by adding about 40 ml of the proper irrigation solution to each pot, preferably once a day in late morning. Seedlings should appear in 5 to 7 days.
7. Record the number of seeds germinated at days 3, 5, 7, 9, 11, 13, and 15 for each treatment group and calculate the final germination percentage at day fifteen. Graph results ***(Be sure students have properly identified the independent and dependent variables and that the graphs are labeled appropriately.)***
8. Combine individual student data to obtain class average.

Anticipated Findings:

(Lead a discussion of these expected results before students conduct the experiment.)

The extent of the salinity effect depends upon plant species and even variety. Sensitivity to salinity also varies with stage of growth, with younger plants being more sensitive. Pots receiving the highest concentrations of salt in the irrigation water will have reduced germination rates and slower seedling growth rates. Results will vary, so multiple tests should be done simultaneously. Several days after germination, seedlings will begin to show signs of salt damage, which include curling up and dampening off of leaves. Some seeds will be unable to complete the germination process. In general, peas will be more resistant to salt concentrations, while progressive effects will be seen with green beans as the salt concentrations become higher.

Data Summary: ***(Present a sample data summary table to students and lead a discussion on how to summarize all data from this experiment.)***

Record the number of seeds germinated on days 5, 7, 9, 11, 13, and 15. Keep watering and record data until one plant reaches the height of about 15 cm. Record all plant heights at that time. Have students use tables to summarize the data (see example that follows). At day 15 calculate average plant height for germinated seeds in each pot. Divide average plant height in pots 2, 3, and 4 by plant height in pot 1 to determine a ratio, based on the control.

Plot for each seed type the number of seeds germinated as a function of time for each salinity level. Also plot percentage germination after 15 days by salinity level for each type of seed.

Sample Data Summary Table
Number of Seeds Germinated by Seed Type and Salt Concentration

	Irrig. Solu. #1	Irrig. Solu. #2	Irrig. Solu. #3	Irrig. Solu. #4
Day 3				
peas				
corn				
beans				
Day 5				
peas				
corn				
beans				
Day 7				
peas				
corn				
beans				
Day 9				
peas				
corn				
beans				
Day 11				
peas				
corn				
beans				
Day 13				
peas				
corn				
beans				
Day 15				
peas				
corn				
beans				

Conclusions: ***(Lead a discussion of these and other conclusions.)***

1. Salt accumulation in the soil decreases seed germination. Higher salt concentrations are associated with increased seed and plant injury.
2. Salt buildup negatively affects plant growth and causes plants to weaken and sometimes die.

Discussion:

(Use a supervised study session or whole class discussion to answer the following questions.)

1 What were the most difficult aspects of conducting this experiment?

2. Did the experimental procedures produce the desired results? (Were you able to determine the effects of salt concentrations in the soil on seed germination and plant growth?)
3. What would you do differently in conducting this experiment a second time?
4. What causes salt accumulation in soils and growing media?
5. What practices do growers use to reduce salt buildup in soils? How do these practices work to lower salt accumulations?
6. What factors affect soil salinity?
7. What are the sources of salts that can accumulate in soils?
8. Why/how does salt in the soil solution affect seed viability and germination?
9. How is salt buildup in soils related to plant transpiration?

Further Investigations: ***(Lead a discussion of these and other ideas.)***

1. Use a variety of seed types, both agronomic and vegetable, to determine the differential effects of soil salinity on germination and seedling growth.
2. Use a combination of salt concentrations in the irrigation solution. Higher concentration will yield more dramatic results.
3. Use different soil types to examine the buffering effects of soil type on soil salinity and corresponding plant growth.
4. Test the degree of tolerance of various plants species to salts. Field crops, vegetable and house plants can be examined.

LS: 06.03.B.PL **Student Handout**

Salinity and Seed Germination

Purpose of Lab:

The purpose of this experiment is to determine the effects of soil accumulation in soils on seed germination and plant growth. By participating in this lab, students will be able to:

1. explain the cause of soil salinity;
2. describe the general effects of salt accumulation in soils on plant growth and development; and
3. explain why/how excessive salt concentrations in soil water have harmful effects on plants.

Research Problem:

What are the effects of salt buildup in soils on seed germination and plant growth?

Your hypothesis is:

Materials:

- twelve 6" pots with drainage holes
- 20 lb. bag of potting soil
- 30 seeds each of peas, green beans, and sweet corn
- four 2-liter containers with lids or caps
- table salt
- gravel
- 50 ml beaker
- balance
- graph paper

Procedures:

1. Place about 2 cm of gravel in the bottom of each of 12 pots. Then add about 9 cm of potting soil to each pot so the soil line is about 3 cm from the top of the pot.
2. Add one liter of tap water to each pot and allow to drain well by tipping and shaking.
3. Make 4 irrigation solutions by adding 36g of NaCl (table salt) to container #4, 24g to container #3, 12g to container #2, and no salt to container #1. Fill each container with 2 liters of tap water.
4. Plant 10 green bean seeds 2 cm deep in each of 4 pots. Plant 4 pots of sweet corn and 4 pots of peas in the same manner.
5. Label all pots with seed type and 1 through 4 for irrigation solution.

6. Place the pots in a sunny location and keep moist (but not wet) by adding about 40 ml of the proper irrigation solution to each pot, preferably once a day in late morning. Seedlings should appear in 5 to 7 days.
7. Record the number of seeds germinated at days 3, 5, 7, 9, 11, 13, and 15 for each treatment group and calculate the final germination percentage at day fifteen. Graph results ***(Be sure you have properly identified the independent and dependent variables and that the graphs are labeled appropriately.)***
8. Combine individual data to obtain class average.

Agriscience Applications:

High soil water concentrations can have adverse effects on plant growth. Although plants require certain salt constituents for growth, some soils contain such large quantities of soluble salts that crop yields are decreased. Soil salinity is most severe in arid, irrigated areas around the world. Salinity may affect as much as 30% of all irrigated land in the U.S., primarily in the southwestern part of the country. A wide variety of major agronomic and horticultural crops are grown in this region of the United States.

In field conditions dissolved salts are usually applied in the irrigation water. Enough salt may accumulate in a few years to reduce the productivity of the soil. Current standard practice in irrigation is to add enough water to permit some drainage to help remove salt buildup in the soil. Artificial drainage is a major investment. Research now underway is aimed at determining optimal amounts of irrigated water to apply, developing simple methods of measuring soil salinity concentrations in the soil.

Salt buildup may also be a problem in greenhouse crops and indoor plants if drainage outlets are not provided in the growing container. Inadequate watering, even with well designed containers, can also lead to salt buildup in the growing medium and eventual death of the plant.

Data Summary

Number of Seeds Germinated by Seed Type and Salt Concentration

	Irrig. Solu. #1	Irrig. Solu. #2	Irrig. Solu. #3	Irrig. Solu. #4
Day 3				
peas				
corn				
beans				
Day 5				
peas				
corn				
beans				
Day 7				
peas				
corn				
beans				
Day 9				
peas				
corn				
beans				
Day 11				
peas				
corn				
beans				
Day 13				
peas				
corn				
beans				
Day 15				
peas				
corn				
beans				

Investigative laboratory Approach

Course:	Agriscience Foundations I
Lesson:	Scientific Method (06.00.IL)

Objectives:

1. Identify the steps involved in the scientific method of investigation.
2. Define common terms used in agriscience research.
3. Properly report scientific findings.

04.01 - 04.05 - 04.06

Equipment, Supplies, References, and Other Resources:

References:

- Cooper, E. L. & Burton, L. D. (2004) *Agriscience: Fundamentals and applications* (3rd Edition). Albany, NY: Delmar. (Unit 1).
- Osborne, E. W. (1994). *Biological science applications in agriculture*. Danville, IL: Interstate Publishers, Inc. (Chapter 1).

Handouts:

- "The Experimentation Process" handout
- LS: 06.00.IL Determining Mass Student Handout

Video:

- Teaching Demonstration

Computer and video projection equipment:

- PowerPoint presentation or Overhead projector
  - TM: 06.00.A The Scientific Method
  - TM: 06.00.B Agriscience Terms
  - TM: 06.00.C Guidelines for Constructing Charts and Graphs

Equipment & Supplies:

- See materials list on lab sheet
- Audio recorder
- Audio tapes

Teacher Directions	Content Outline and/or Procedures
REVIEW	None – new unit
INTEREST APPROACH	***Push "record" on audio recorder*** Ask the students to explain the process by which scientists conduct investigations. Ask them to create a step by step procedure. Then ask for volunteers to share their procedure with the rest of the class. Compare student examples with the procedure suggested in the lesson.

Teacher Directions	Content Outline and/or Procedures
OBJECTIVES	
1. Identify the steps involved in the scientific method of investigation. TM: 06.00.A – The Scientific Method	A. The scientific method has five steps. 1. Define the problem—usually stated as a question. a. What do you want to know? 2. Gather ***data*** (facts and information) about the problem. a. Summarize past experiences. b. Review other research results. 3. Suggest possible answers or solutions. a. A ***hypothesis*** is a prediction of the results of an experiment. b. Write the hypothesis before beginning the experiment. 4. Test the hypothesis. a. Conduct an experiment to test the hypothesis. b. Summarize the data collected in organized charts or tables. 5. Evaluate the results. a. Examine the findings of the experiment. b. Draw ***conclusions*** or judgments made on the basis of the findings.
2. Define common terms used in agriscience research. TM: 06.00.B – Agriscience Terms	B. Key terms used in agriscience experiments 1. Independent variable: Will affect another variable a. Known as *treatment* 2. Dependent variable: Observed variable; expected to change due to independent variable 3. Replication - exact duplication a. Allows for validation
3. Properly report scientific findings TM: 06.00.C – Guidelines for	C. Data may be summarized and reported in many different ways. 1. Descriptive statistics are one common method. Common descriptive statistics are: a. Means – which are averages b. Frequency distributions – which are simply counts of how many times something occurred. c. Percentages

Teacher Directions	Content Outline and/or Procedures
Constructing Charts and Graphs	2. Data can be visually summarized using charts and graphs. When constructing a graph, there are certain guidelines to follow: a. The independent variable (X) is reported on the horizontal axis (x-axis). b. The dependent variable (Y) is reported on the vertical axis (y-axis). c. Be sure to label the axis and title the graph.
REVIEW/SUMMARY	Use questioning to determine if students understand the content material of this lesson
APPLICATION	Complete LS 06.00.IL Determining Mass

LS: 06.00.IL **Teacher Instructions**

Determining Mass

Interest Approach: ***(Present as follows.)***

Ask students, “What is mass?” Select a few students to offer their definition. Then hold up a piece of bubble gum and ask the students, “What will happen to the mass (weight) of this piece of bubble gum when I chew it?”

!!Teacher note: Do NOT present the research problem to the students. Instead, challenge them to phrase the research question themselves.

Research Problem:

What effect does chewing have on the mass of bubble gum?

Purpose: ***(Present to class and discuss.)***

The purpose of this experiment is to observe the effect chewing has on the mass of bubble gum. Also, this experiment will familiarize students with the scientific method.

!!Teacher note: Pass out a copy of “The Experimentation Process” handout to each student. Have students work in lab groups to plan the design of their experiment by following the steps in this handout. Their written responses to each step in the experimentation process will constitute their design for this experiment. Allow groups to use different designs for their experiments as materials, time, and other resources allow. Require each group to develop a written design for their experiment BEFORE they proceed with conducting the experiment.

!!Teacher note: Do NOT give the materials list and procedures to students. Instead, use them as a guide as you help students plan the design of their experiments.

Materials:

- Balances or scales
- Bubble gum
- Graph paper

Procedures:
(2-4 students per group)

7. Weigh one piece of bubble gum. Record the mass.
8. Develop a hypothesis on the effect chewing will have on the mass of the bubble gum. Record your hypothesis.

9. Chew the bubble gum for 30 seconds. Using the wrapper as a weigh paper, determine the mass of the bubble gum.
10. Repeat step #3 until bubble gum has been chewed for 5 minutes.
11. Graph the results of your findings. ***(Be sure students have properly identified the independent and dependent variables and that the graphs are labeled appropriately.)***
12. Evaluate hypothesis

!!Teacher note: Do NOT give the students sample formats for data summary tables. Instead challenge them to develop formats themselves and use the sample provided to guide your supervision of their work.

Data Summary:

Observations should be taken of the experiment at regular intervals. Have students complete a simple data summary table stating their observations.

Sample Data Summary Table

Time	0:00	0:30	1:00	1:30	2:00	2:30	3:00	3:30	4:00	4:30	5:00
Mass											

!!Teacher note: Challenge your students to first identify in writing their conclusions, then use the following list to verify and modify their ideas.

Conclusions: ***(Lead a discussion of these and other conclusions.)***
1. Mass of the bubble gum decreased as it was chewed.
2. The decline in mass was greatest in the beginning. As time passed, the rate of decline slowed.

Discussion: ***(Use a supervised study session or whole class discussion to answer the following questions.)***

1 What were the most difficult aspects of conducting this experiment?
2. Did the experimental procedures produce the desired results? (Were you able to answer the research question?)
3. What would you do differently in conducting this experiment a second time?
4. Why did the rate at which the mass changed slow down?

!!Teacher note: Do NOT give the following ideas to your students. Instead, challenge them to identify their own ideas for further experimentation. Then lead a class discussion on how such experiments could be designed to answer their research objectives.

Further Investigation: ***(Lead a discussion of these and other ideas.)***

1 Compare different types of gum.
2. Instead of using time as the dependent variable, count the number of chews.

!!Teacher note: Have each student or lab group select one of the ideas for further investigation and describe in writing the design for that experiment. (Address each step of the experimentation process – see handout.)

Questions: ***(Lead a discussion of these and other questions.)***

What was your hypothesis? Was it correct?

What is the dependent variable in this experiment? ***Answer: Time***

What is the independent variable in this experiment? ***Answer: Mass***

LS: 06.00.IL **Student Handout**

Determining Mass

Purpose:

The purpose of this experiment is to observe the effect chewing has on the mass of bubble gum. Also, this experiment will familiarize students with the scientific method.

Research Problem:

Your hypothesis is:

Materials: (Use additional pages if needed.)

Procedures: (Use additional pages if needed.)

Data Summary: (Use additional pages if needed.)

Questions:

What was your hypothesis? Was it correct?

What is the dependent variable in this experiment?

What is the independent variable in this experiment?

Course:	Agriscience Foundations I
Lesson:	Examining Plant Structures and Functions (06.01.IL)

Objectives:

1. Describe the cellular structure of plants.
2. Identify the major parts of plants and explain their functions.
3. Distinguish between plants based on seed cotyledons.
4. Explain the absorption and transport systems of plants.

06.01: Describe the structure functions of plant parts including roots, stems, leaves, and flowers.

Equipment, Supplies, References, and Other Resources:

References:

- Cooper, Elmer L. *Agriscience Fundamentals and Applications*, Third Edition. Albany, New York: Delmar Publishers, Inc., 2004.
- Lee, Jasper S. and Diana L. Turner. *AgriScience,* Third Edition. Danville, Illinois: Interstate Publishers, Inc., 2003.

Handouts:

- Lab Sheet 06.01.IL Osmotic Turgescence (Pressure) Student Handout
- "The Experimentation Process" handout

Video:

- Teaching Demonstration

Computer and video projection equipment:

- PowerPoint presentation or Overhead projector
    - TM: 06.01.A Major Parts of a Plant Cell
    - TM: 06.01.B Functions of Leaves, Stems, Roots, and Flowers
    - TM: 06.01.C Parts of a Typical Stem
    - TM: 06.01.E Specialized Stems
    - TM: 06.01.F Kinds of Roots
    - TM: 06.01.G Leaf types
    - TM: 06.01.H Comparison of Monocot and Dicot Seed
    - TM: 06.01.K Arrangement of Tissues in Stems
    - TM: 06.01.L Roots
    - TM: 06.01.M Absorption
    - TM: 06.01.N Stomata

Equipment & Supplies:

- Plant specimen (Interest Approach)
- See materials list on lab sheet
- Audio recorder
- Audio tapes

Teacher Directions	Content Outline and/or Procedures
REVIEW	None – new unit
INTEREST APPROACH	***Push "record" on audio recorder*** Bring a small plant specimen (about 18 inches long) that has been pulled up so that leaves, stems, and roots are obvious. A specimen with flowers and/or fruit is preferred. Ask students to name the different parts of the specimen. As they do, have them describe the function of the part and how it is useful to humans. Move from the interest approach into the objectives and anticipated problems for the lesson.
OBJECTIVES	
1. Describe the cellular structure of plants. TM: 06.01. A Major Parts of a Plant Cell	I. Cells are the structural basis of all living organisms. A. A cell is a tiny structure that forms the basic building blocks of plants. 1. All organisms are made of one or more cells. 2. Protoplasm in cells carries out life processes. B. Plants are multi-cellular organisms, meaning that they have many cells. 1. Some cells have specific functions. 2. Cell specialization is the presence of cells that perform unique activities for a plant. (Flowers, leaves, roots, and stems are made of specialized cells.) C. Cells are formed into groups that work together. 1. Tissue is formed by groups of cells that are alike in activity and structure. 2. An organ is formed by tissues that work together to perform specific functions. 3. An organ system is a group of organs that works together to perform a function. D. Cell structure is the organization of the material that forms a cell. 1. Plant cells have three major parts: wall, nucleus, and

Teacher Directions	Content Outline and/or Procedures
	cytoplasm. 2. The cell wall surrounds the cell and controls the movement of materials into and out of the cell. 3. The nucleus is near the center of a cell and contains protoplasm, chromosomes, and other structures that control cell activity. 4. The cytoplasm is a thick solution inside the cell wall surrounding the nucleus. 5. Plant cells have many additional parts, including: chloroplasts, nucleolus, vacuole, mitochondria, and golgi body.
2. Identify the major parts of plants and explain their functions. TM: 06.01.B Functions of Leaves, Stems, Roots, and Flowers TM: 06.01.C Parts of a Typical Stem TM: 06.01.E Specialized Stems	II. Plants are comprised of vegetative and reproductive parts. A. The major vegetative parts of plants are stems, leaves, and roots. 1. A stem is the central axis that supports the leaves, connects them with the roots, and transports water and other materials between the leaves and roots. Stems vary widely in appearance based on the species of plant. Stems may be vertical or horizontal and modified for climbing and to store water and food. Several specialized kinds of stems are important: a. Rhizome—A rhizome is an underground stem that grows horizontally. It may grow adventitious roots and stems to develop as a separate plant. Examples include iris and wild ginger. b. Tuber—A tuber is an enlarged part of a stem that grows underground. A tuber can develop into a separate plant. Examples include potatoes and yams. c. Tendril—A tendril is a threadlike leafless growth on a stem that attaches itself around other stems and objects. Tendrils typically grow in a spiral shape. After attaching itself, it holds the stem in position. Vines and climbing plants often have tendrils. Examples include sweet peas and cucumbers.

Teacher Directions	Content Outline and/or Procedures
	d. Stolon—A stolon is an above ground stem that grows horizontally and propagates new plants. Strawberries are well known as examples of plants that multiply using stolons.
	e. Bulb—A bulb is an underground food-storage organ consisting of flattened, fleshy stem-like leaves with roots on the lower side. Examples of bulbs are onions and daffodils.
TM: 06.01.F Kinds of Roots	f. Corm—A corm is a food storage structure at the end of a stem that grows underground. It is an enlarged or swollen stem base. Examples include gladiolus and crocus.
	g. Cladophyll—A cladophyll is a leaflike branch that resembles a leaf. It is also called a cladode. A cladophyll functions much like a leaf.
TM: 06.01.G Leaf types	2. A root is the part of a plant that grows in the soil or other media. Roots anchor plants, absorb water and minerals, and store food. The root system structure varies widely depending on the species of plant. Overall, roots can be classified as two major types:
	a. Fibrous—A fibrous root system is made of many small roots and spread throughout the soil.
	b. Taproot—A taproot system is made of one primary root with a number of small secondary roots.
	3. A leaf is typically a large, flat, green organ attached to the stem. Leaves carry out photosynthesis, transpiration, and may store food. Shape, arrangement, and other features vary widely with the species of plant. There are two major kinds of leaves and three major types of arrangements:
	a. Simple—A simple leaf has only one blade.
TM: 06.01.B Functions of Leaves, Stems, Roots, and Flowers	b. Compound—A compound leaf is divided into two or more leaflets
	c. Leaf attachment also varies. This refers to the spacing and arrangement of leaves on the stem of a plant. The major kinds of attachment

Teacher Directions	Content Outline and/or Procedures
	are: (1) Alternate—Alternate leaf arrangement is one leaf at each node on a stem. (2) Opposite—Opposite leaf arrangement is two leaves are attached at nodes opposite each other. (3) Whorled—Whorled leaf arrangement is three or more leaves are at each node. B. The major reproductive parts of plants are flowers, seed, and fruit. 1. A flower is a part containing the reproductive organs. The types of flowers vary considerably. In general, flowers produce pollen and ovules. Fertilization occurs when a pollen cell unites with an ovule. 2. Seed are formed by fertilized ovules and contain new plant life. 3. Fruit are the ovaries which develop to protect and nourish the developing seed. The kinds and nature of fruit vary widely.
3. Distinguish between plants based on seed cotyledons. TM: 06.01.H Comparison of Monocot and Dicot Seed	III. A cotyledon is the fleshy structure within a seed that contains food for a developing embryo. A. Depending on the plant species, a seed may have one or two cotyledons. B. A plant species producing seed with one cotyledon is a monocotyledon, or monocot. 1. All grasses are monocots. Corn, wheat, oats, Bermuda grass, and sugarcane are examples of monocots. 2. Monocot plants have long, narrow leaves with parallel veins. All leaves branch from the main stem. 3. Stems are non-woody and tend to have a large area of pith in the center. C. A plant species producing seed with two cotyledons is a

Teacher Directions	Content Outline and/or Procedures
	dicotyledon, or dicot. 1. All plants other than grasses are dicots. Soybeans, trees, lettuce, sunflowers, and petunias are examples of dicots. 2. Dicot plants have broad leaves with a net-type of veins. 3. Stems are often long and branching. They may be woody or non-woody, depending on the plant species.
4. Explain the absorption and transport systems of plants. TM: 06.01.K Arrangement of Tissues in Stems TM: 06.01.L Roots TM: 06.01.M Absorption TM: 06.01.N Stomata	IV. Water and nutrients are primarily absorbed by the roots and transported throughout the plant by various tissues in the roots, stems, and leaves. A. Roots have tiny root hairs covered with thin membranes that allow water and nutrients to enter. 1. Osmosis is the movement of water from greater concentration in the soil or media to lower concentration in the root. 2. Water enters until the concentration in the root is equal to the concentration outside the root. 3. The water entering roots also carries inorganic substances known as nutrients. B. After absorption by roots, water is passed from cell to cell until it reaches the xylem. 1. Xylem is tissue, formed as tubes, that conducts water up the stem and to the leaves. 2. The petiole of the leaf takes the water from the xylem in the stem to the leaf veins, which distribute it throughout the leaf. C. Leaves lose water by transpiration. 1. Transpiration occurs through tiny stomata on leaves. 2. Transpiration creates somewhat of an upward pull that assists the xylem in moving water and nutrients. D. Manufactured food is conducted from the leaves through the stems to the roots in phloem tissue.

Teacher Directions	Content Outline and/or Procedures
	1. Phloem is the tissue that conducts sugars, proteins, hormones, dissolved materials, and salts from leaves to other parts of a plant. 2. The structure is observed as elongated sieve-type cells that form tube structures in stems.
REVIEW/SUMMARY	Focus the review and summary of the lesson on the student learning objectives. Have students explain the content associated with each objective. Use specimens of plant materials for students to use in demonstrating their knowledge of the objectives. Use student responses as the basis for reteaching. Complete Examining Plant Structures and Functions worksheet and/or have students complete questions at the end of the chapters in the text.
APPLICATION	Complete LS: 06.01.IL Osmotic Turgescence (Pressure)

LS: 06.01.IL **Teacher Instructions**

Osmotic Turgescence (Pressure)

Interest Approach: ***(Present as follows.)***

Bring to class two sets of bean seeds. One of the sets should be soaked in water for approximately four hours prior to class. As the students to compare the two sets of seeds. Ask them why the seeds that had been soaked are larger.

Agriscience Applications: ***(Discuss.)***

When cells in growing tissues split and enlarge as water and nutrients are absorbed and used to make new cellular materials, a tremendous force is produced. This force is called osmotic turgescence. The strength of the force depends upon characteristics of the seed. Hydraulic pressure causes a stretching effect on the cell walls, making cell enlargement (growth) possible.

Plant cells are osmotic systems. The concentration of water is less inside the cell than outside. This osmotic process generates the cell's internal hydraulic pressure. As water enters the cell, its volume and hydraulic pressure increase.

!!Teacher note: Do NOT present the research problem to the students. Instead, challenge them to phrase the research question themselves.

Research Problem:

How much pressure is exerted by a seed as it takes up water for germination?

Purpose: ***(Present to class and discuss.)***

The purpose of this experiment is to observe the pressure exerted by germinating seeds.

!!Teacher note: Pass out a copy of "The Experimentation Process" handout to each student. Have students work in lab groups to plan the design of their experiment by following the steps in this handout. Their written responses to each step in the experimentation process will constitute their design for this experiment. Allow groups to use different designs for their experiments as materials, time, and other resources allow. Require each group to develop a written design for their experiment BEFORE they proceed with conducting the experiment.

!!Teacher note: Do NOT give the materials list and procedures to students. Instead, use them as a guide as you help students plan the design of their experiments.

Materials:

lima bean seeds (or other large beans)
dry, clean sand
pint jar with lid
masking tape
box or pan
pen or pencil

Procedures:

(4 students per group)

Place an equal amount of beans and sand in a jar. Shake the jar to mix the beans and sand completely. Push the sand in tightly. Fill the jar to the top with sand.
Wet the sand, but do not put enough water into the jar to flood it.
Screw the lid on tightly
Label each jar by putting your name on a piece of masking tape on the lid of the jar.
Place the jar on a large pan or box in an area away from students. (This contains the mess of broken jars and aids in clean up afterwards.)
Observe what happens to the jar after a few hours. Record observations.

!!Teacher note: Do NOT give the students sample formats for data summary tables. Instead challenge them to develop formats themselves and use the sample provided to guide your supervision of their work.

Data Summary:

Observations should be taken of the experiment at regular intervals. Have students complete a simple data summary table stating their observations. Be sure student observations are written in complete sentences and with good sentence structure.

Sample Data Summary Table

Time	Observation

!!Teacher note: Challenge your students to first identify in writing their conclusions, then use the following list to verify and modify their ideas.

Conclusions: ***(Lead a discussion of these and other conclusions.)***

1. Expanding seeds create enough pressure to break glass jars.

Discussion: ***(Use a supervised study session or whole class discussion to answer the following questions.)***

1 What were the most difficult aspects of conducting this experiment?
2. Did the experimental procedures produce the desired results? (Were you able to observe the pressure exerted by germinating seeds?)
3. What would you do differently in conducting this experiment a second time?
4. Why did some jars break more quickly than others?
5. Why did some jars not break at all?
6. What was the purpose of the sand in the experiment?

!!Teacher note: Do NOT give the following ideas to your students. Instead, challenge them to identify their own ideas for further experimentation. Then lead a class discussion on how such experiments could be designed to answer their research objectives.

Further Investigation:

1 Compare different types of seeds.
2 Vary the amount of sand and seed placed in each jar.
3 Vary the temperature or light received by the jar to see if they have an effect on water uptake by the seed.

!!Teacher note: Have each student or lab group select one of the ideas for further investigation and describe in writing the design for that experiment. (Address each step of the experimentation process – see handout.)

LS: 06.01.IL Student Handout

Osmotic Turgescence (Pressure)

Purpose:

The purpose of this experiment is to observe the pressure exerted by germinating seeds.

Research Problem:

Your hypothesis is:

Materials: (Use additional pages if needed.)

Procedures: (Use additional pages if needed.)

Agriscience Applications:

When cells in growing tissues split and enlarge as water and nutrients are absorbed and used to make new cellular materials, a tremendous force is produced. This force is called osmotic turgescence. The strength of the force depends upon characteristics of the seed. Hydraulic pressure causes a stretching effect on the cell walls, making cell enlargement (growth) possible.

Plant cells are osmotic systems. The concentration of water is less inside the cell than outside. This osmotic process generates the cell's internal hydraulic pressure. As water enters the cell, its volume and hydraulic pressure increase.

Data Summary: (Use additional pages if needed.)

Course: Agriscience Foundations I

Lesson: Determining the Importance of Photosynthesis and Respiration (06.02.IL)

Objectives:

1. Explain photosynthesis and its importance.
2. Write the chemical equation for photosynthesis and explain it.
3. Explain how light and dark reactions differ.
4. Define respiration and explain why it is important.
5. List four factors that affect the rate of respiration.
6. Explain the importance of transpiration to plants.

Student Performance Standards Addressed:

06.02: Describe the processes of plant growth including photosynthesis, respiration, and nutrient uptake.

Equipment, Supplies, References, and Other Resources:

References:

- Cooper, Elmer L. *Agriscience Fundamentals and Applications*, Third Edition. Albany, New York: Delmar Publishers, Inc., 2004.
- Lee, Jasper S. and Diana L. Turner. *AgriScience,* Third Edition. Danville, Illinois: Interstate Publishers, Inc., 2003.

Handouts:

- LS: 06.02.IL Transpiration in Plants Student Handout
- “The Experimentation Process” handout

Video:

- Teaching Demonstration

Computer and video projection equipment:

- PowerPoint presentation or Overhead projector
  - TM: 06.02.A Energy Flow
  - TM: 06.02.B Photosynthesis Equation
  - TM: 06.02.C Two Major Phases of Photosynthesis
  - TM: 06.02.D Comparison of Photosynthesis and Respiration
  - TM: 06.02.E Factors Affecting the Rate of Respiration
  - TM: 06.02.F Transpiration and Gas Exchange in Leaves
  - TM: 06.02.G Factors Affecting the Rate of Transpiration

Equipment & Supplies:

- See materials list on lab sheet
- Audio recorder
- Audio tapes

Teacher Directions	**Content Outline and/or Procedures**
REVIEW	***Push "record" on audio recorder*** Quickly review the objectives of Lesson 06.01.IL Examining Plant Structures and Functions.
INTEREST APPROACH	Start the lesson by shutting off the lights in the classroom. Ask the students if they could survive and continue to make energy if they were kept in the dark. Ask students what effect complete darkness would have on other mammals. Now ask the students what effect complete darkness would have on plants.
OBJECTIVES	
1. *Explain photosynthesis and its importance.* TM: 06.02.A Energy Flow TM: 06.02.C Two Major Phases of Photosynthesis TM: 06.02.B Photosynthesis Equation	I. Photosynthesis is the manufacture of food by plant cells. A. Sugar is the major product of photosynthesis and provides energy for the plant. B. There are two phases to the photosynthesis process. 1. Energy gathering—Plant leaves soak up sunlight. 2. Sugar making—Plants convert energy from sunlight into stored chemical energy. a. Chemical energy rearranges carbon dioxide in the plant in the presence of chlorophyll to form sugar. b. Glucose, a simple sugar, is formed. C. Photosynthesis is the most important reaction on earth. All life forms are dependent on the reaction. 1. Occurs in the chloroplasts 2. CO2 + light + chlorophyll + H2O _ C6H12O6 (glucose) + H2O + O2 D. In order for photosynthesis to occur, several things must be present. 1. Chlorophyll—green colored substance in plants. 2. Light—Leaves absorb necessary energy from the sun's rays or artificial light. 3. Carbon Dioxide—Enters the plant through structure called

Teacher Directions	Content Outline and/or Procedures
	stomata in the leaves. Carbon dioxide is split during photosynthesis. 4. Water—Water is also split during photosynthesis.
2. *Write the chemical equation for photosynthesis and explain it.* TM: 06.02.B Photosynthesis Equation	II. Photosynthesis is a series of chemical reactions that yields sugars, water, and oxygen. A. The chemical equation of photosynthesis can be written in words: Six molecules of carbon dioxide plus twelve molecules of water in combination with a healthy plant and some form of light energy, to make one molecule of sugar plus six molecules of water and six molecules of oxygen. B. The products of photosynthesis include carbohydrates in the form of sugars and starches as well as water and oxygen.
3. *Explain how light and dark reactions differ.*	III. Photosynthesis is a series of complex reactions that have been divided into two major phases. These two major phases have been named the light and dark reactions. A. Light Reactions— 1. The light reactions are also known as light dependent reactions. Light allows energy to be released in the form of ATP which can be used by the plant in the splitting of water and the release of oxygen. 2. The pigments in chloroplasts absorb light energy to form NADPH and ATP to be used in the breakdown of CO2 in the dark reactions. B. Dark Reaction— 1. Also known as light independent reactions. 2. A chemical known as RuBP (rubilose biphosphate) absorbs carbon. Carbon dioxide and RuBP join together and go through a process called the Calvin cycle. The Calvin cycle reduces carbon dioxide to manufacture carbohydrates. The NADPH and ATP synthesis from the light reactions provide the energy needed to power the Calvin cycle. 3. As a result of the Calvin cycle, one molecule of glucose is formed.
4. *Define respiration and explain why it is important.*	IV. ***Respiration*** is the process by which an organism provides its cells with oxygen so energy can be released from digested food. Respiration takes place in all living cells at all

Teacher Directions	Content Outline and/or Procedures
TM: 06.02.D Comparison of Photosynthesis and Respiration	times. A. ***Mitochondria*** are energy processing factories for plants. Respiration takes place in the mitochondria of all cells. B. Respiration yields the opposite results as photosynthesis. The process of photosynthesis absorbs energy, consumes carbon dioxide and releases oxygen. Respiration uses energy, consumes oxygen and releases carbon dioxide.
5. *List four factors that affect the rate of respiration.* TM: 06.02.E Factors Affecting the Rate of Respiration	V. Temperature, oxygen, soil conditions, and light can affect the rate of respiration. A. Temperature—There is a direct relationship between respiration and temperature, as the temperature increases so does the rate of respiration. B. Oxygen—Oxygen is required for respiration to take place. As oxygen levels decrease so does the rate of respiration. C. Soil conditions—Soil containing large quantities of water cause the rate of respiration to decrease because of the lack of oxygen. D. Light—The amount of energy produced by photosynthesis in low light conditions is reduced. Therefore the amount of energy available to conduct respiration is lower.
6. *Explain the importance of transpiration in plants.* TM: 06.02.F Transpiration and Gas Exchange in Leaves TM: 06.02.G Factors Affecting the Rate of Transpiration	VI. ***Transpiration*** in plants is the loss of water by evaporation through structures called stomata. ***Stomata*** are pores or openings in the plant that allow for the exchange of water and other substances. Transpiration in plants is similar to perspiration in humans. A. Water molecules and transpiration together form a force that is essential for water movement through plants. 1. As water evaporates through the stomata of plant, it creates a pull that aids in the absorption of water by the roots. (An analogy of using a straw to drink will help students to visualize this process.) 2. Transpiration is a vital link in the hydrologic cycle. Ninety-nine percent of all water taken in by the plant is lost to transpiration. Therefore, transpiration contributes significantly to the generation of rainfall.

Teacher Directions	Content Outline and/or Procedures
	B. Factors affecting the rate of transpiration include: 1. Wind speed—the relationship between wind speed and transpiration is a direct relationship. 2. Temperature—as temperature increases so does the rate of transpiration because the plant uses transpiration as a mechanism to cool itself. Once again there is a direct relationship between temperature and transpiration. 3. Humidity—Humidity influences the rate of transpiration because if the air is already saturated with water vapor, there will be a decrease in the rate of evaporation. 4. Drought—If the plant is experiencing drought conditions it will close the stomata to prevent needed water from escaping. When the plant's stomata are closed transpiration does not take place.
REVIEW/SUMMARY	Focus the review and summary of the lesson around the student learning objectives. Call on students to explain the content associated with each objective. Questions at the end of each chapter in the recommended textbooks may also be used in the review/summary. Complete the Determining the Importance of Photosynthesis and Respiration worksheet.
APPLICATION	Complete LS: 06.02.IL Transpiration in Plants

LS: 06.02.IL **Teacher Instructions**

Transpiration in Plants

Interest Approach: ***(Present as follows)***

Ask three to five students to volunteer participate in a race. Give each volunteer a penny, a pipette, and cup of water. The rules of the competition are simple, the person who can put the largest numbers of water drops on the top of the penny without getting the table wet wins. You may also ask for another set of students to volunteer to help count the number of drops on each student's penny. After the "race" is over, ask the competitors to describe to the rest of the class what happened. Why were you able to get so many drops on the penny? Describe the properties of adhesion and cohesion. Relate to transpiration in plants.

Agriscience Applications: ***(Discuss)***

Transpiration is the loss of water through plant leaves. Over 90% of all water absorbed by the plant is lost through this process. This water loss occurs through the stomata, which are located on the underside of plant leaves. Some plants also have stomata on the upper side of the leaves. The stomata are pores that open and close under certain conditions. In addition to allowing water vapor to escape, the stomata also allow the inward movement of atmospheric carbon dioxide which is used in photosynthesis.

Osmosis and diffusion are the primary means by which plants absorb water from the soil and release water through transpiration. Diffusion is the movement of molecules (water) from a region of higher concentration to a region of lower concentration. Transpiration water losses occur by diffusion. Osmosis is the diffusion of water through a differentially permeable membrane. Water enters the cell by osmosis then travels across several membranes until it moves into the xylem. It is then transported to the leaves where much of the water is diffused through the stomata.

The upward movement of water from the roots to the leaves is known as the transpiration stream. As water is lost from the outer tissues of the leaf, water moves in from interior tissue. Differences in osmotic pressure between cell layers causes this "suction" of water from the roots to the leaves. This process is facilitated by the cohesion properties of water. Cohesion is the attraction between like molecules (water to water). Adhesion is the attraction between unlike molecules (water to plant tissue).

Light, carbon dioxide concentrations, and water content in plant tissue affect the stomata. Air movement and humidity affect the opening and closing the stomata. Changes in turgor pressure of the guard cells cause the stomatal pores to open and close. When the stomata are closed, water loss is reduced. However, if the stomata are closed, carbon dioxide cannot enter the plant. Thus prohibiting photosynthesis from occurring.

Maintaining adequate soil moisture is a critical management practice in plant growth for both indoor and outdoor growing conditions. For greenhouse crops, watering is probably the most time-consuming task required in growing a given crop. Fortunately, the high labor costs of maintaining proper moisture levels is somewhat offset by the relatively low cost of water as an input for greenhouse crops.

In outdoor growing conditions, including vegetables, turf, and field crops, soil moisture fluctuates much more and reaches more extreme levels than in more controlled, indoor environments. Thus, maintaining adequate soil moisture levels in outdoor conditions is much more of a challenge, due to weather factors beyond the grower's control. Soil moisture levels are increased either by natural means (rainfall) or artificially via irrigation. Moisture losses occur primarily through the evaporation of water from the upper soil layers through the loss of water through leaf surfaces and other plant parts (transpiration). The rate of water loss as a result of transpiration is primarily dependent upon weather (i.e., temperature and humidity). Thus, growers must seasonally adjust their crop schedules according to the water intake and loss responses of the plants being grown.

!!Teacher note: Do NOT present the research problem to the students. Instead, challenge them to phrase the research question themselves.

Research Problems:

1. What effect does leaf size and number have on plant transpiration rate?
2. What effect does air movement have on plant transpiration rate?

Purpose: ***(Present to class and discuss)***

The purpose of this experiment is to observe the general rate of transpiration in plants and to examine the effects of wind on transpiration rate. Through this lab, students will be able to:

1. describe the biological process of transpiration in plants;
2. identify the factors that affect transpiration and explain why and how these effects are realized;
3. measure transpiration rates in given test plants; and
4. explain the relationship between transpiration and soil moisture management practices on plant growth.

!!Teacher note: Pass out a copy of "The Experimentation Process" handout to each student. Have students work in lab groups to plan the design of their experiment by following the steps in this handout. Their written responses to each step in the experimentation process will constitute their design for this experiment. Allow groups to use different designs for their experiments as materials, time, and other resources allow. Require each group to develop a written design for their experiment BEFORE they proceed with conducting the experiment.

!!Teacher note: Do NOT give the materials list and procedures to students. Instead, use them as a guide as you help students plan the design of their experiments.

Materials:

- Four 50-milliliter graduated cylinders
- Modeling clay
- Cooking oil
- Cuttings from a large-leafed, herbaceous plant
- Water
- Electric fan
- Graph paper

Procedures:
(4 students per group)

10. Take four stem cuttings (8 to 10 inches long) from stock plants. Choose stem cuttings with leaves of relatively equal size. Remove all but one leaf from two of the cuttings. Leave three or four leaves on each of the other two cuttings.
11. Add water to the four graduated cylinders.
12. Place the stem of the cuttings so they extend well below the water line in the graduated cylinders.
13. Pour 2 milliliters of cooking oil on top of the water in the graduated cylinder to prevent evaporation losses.
14. Gently pack modeling clay around the stem at the cylinder opening to provide support for the plant. Be careful not to crush the stem. Try to establish initial water line near 40 milliliters.
15. Record the water level in each cylinder.
16. Place all four cylinders under the same environmental conditions (temperature, light, etc.) with one exception. Two of the cylinders (one with a single leaf and one with multiple leaves) should be placed in front of a low-speed fan.
17. Record the water level in each cylinder on a regular basis.
18. Summarize the data. Graph the results ***(Be sure students have properly identified the independent and dependent variables and that the graphs are labeled appropriately.)***

!!Teacher note: Do NOT give the students sample formats for data summary tables. Instead challenge them to develop formats themselves and use the sample provided to guide your supervision of their work.

Data Summary:

Observations should be taken of the experiment at regular intervals. Have students complete the simple data summary table. Students should graph the water loss the occurred during the time of the experiment.

Treatment	Initial Reading	End Day 1		Beginning Day 2		End of Day 2	
		Reading	Net Change	Reading	Net Change	Reading	Net Change
1 leaf, no fan							
3-4 leaves, no fan							
1 leaf, fan							
3-4 leaves, fan							

!!Teacher note: Challenge your students to first identify in writing their conclusions, then use the following list to verify and modify their ideas.

Conclusions: ***(Lead a discussion of these and other conclusions.)***

1. Moisture is lost through the leaves.
2. The greater the number of leaves (leaf surface area), the greater the loss from transpiration.
3. Increased airflow (up to a certain speed) will increase the rate of transpiration.

Discussion:

(Use a supervised study session or whole class discussion to answer the following questions.)

1. What were the most difficult aspects of conducting this experiment?
2. Did the experimental procedures allow you to answer the research question?
3. What would you do differently in conducting this experiment a second time?
4. What effect would transpiration have on the way you would manage a greenhouse?
5. What plants would be more susceptible to greater losses of moisture due to transpiration?
6. Why were herbaceous plants selected for this experiment?
7. Why does air movement tend to increase the rate of transpiration?
8. What would happen if transpiration rate exceeded the rate at which the plant could replenish the water in its tissues?
9. At what point does an increase in air speed decrease transpiration? Why?
10. What is the relationship between rate of transpiration and leaf surface area?
11. What causes water to be pulled upward into the leaf stems?

!!Teacher note: Do NOT give the following ideas to your students. Instead, challenge them to identify their own ideas for further experimentation. Then lead a class discussion on how such experiments could be designed to answer their research objectives.

Further Investigation:

(Lead a discussion of these and other ideas.)

1. Examine the effects of additional environmental factors such as light intensity, temperature, and humidity on the rate of transpiration in plants.
2. Examine the rate of transpiration in plants that are growing under various degrees of soil moisture.

!!Teacher note: Have each student or lab group select one of the ideas for further investigation and describe in writing the design for that experiment. (Address each step of the experimentation process – see handout.)

LS: 06.02.IL **Student Handout**

Transcription in Plants

Purpose of this Lab:

The purpose of this experiment is to observe the general rate of transpiration in plants and to examine the effects of wind on transpiration rate. Through this lab, students will be able to:

1. describe the biological process of transpiration in plants;
2. identify the factors that affect transpiration and explain why and how these effects are realized;
3. measure transpiration rates in given test plants; and
4. explain the relationship between transpiration and soil moisture management practices on plant growth.

Research Problems:

Your hypothesis is:

Materials: (Use additional pages if needed.)

Procedures: (Use additional pages if needed.)

Agriscience Applications:

Transpiration is the loss of water through plant leaves. Over 90% of all water absorbed by the plant is lost through this process. This water loss occurs through the stomata, which are located on the underside of plant leaves. Some plants also have stomata on the upper side of the leaves. The stomata are pores that open and close under certain conditions. In addition to allowing water vapor to escape, the stomata also allow the inward movement of atmospheric carbon dioxide which is used in photosynthesis.

Osmosis and diffusion are the primary means by which plants absorb water from the soil and release water through transpiration. Diffusion is the movement of molecules (water) from a region of higher concentration to a region of lower concentration. Transpiration water losses occur by diffusion. Osmosis is the diffusion of water through a differentially permeable membrane. Water enters the cell by osmosis then travels across several membranes until it moves into the xylem. It is then transported to the leaves where much of the water is diffused through the stomata.

The upward movement of water from the roots to the leaves is known as the transpiration stream. As water is lost from the outer tissues of the leaf, water moves in from interior tissue. Differences in osmotic pressure between cell layers causes this “suction” of water from the roots to the leaves. This process is facilitated by the cohesion properties of water. Cohesion is the attraction between like molecules (water to water). Adhesion is the attraction between unlike molecules (water to plant tissue).

Light, carbon dioxide concentrations, and water content in plant tissue affect the stomata. Air movement and humidity affect the opening and closing the stomata. Changes in turgor pressure of the guard cells cause the stomatal pores to open and close. When the stomata are closed, water loss is reduced. However, if the stomata are closed, carbon dioxide cannot enter the plant. Thus prohibiting photosynthesis from occurring.

Maintaining adequate soil moisture is a critical management practice in plant growth for both indoor and outdoor growing conditions. For greenhouse crops, watering is probably the most time-consuming task required in growing a given crop. Fortunately, the high labor costs of maintaining proper moisture levels is somewhat offset by the relatively low cost of water as an input for greenhouse crops.

In outdoor growing conditions, including vegetables, turf, and field crops, soil moisture fluctuates much more and reaches more extreme levels than in more controlled, indoor environments. Thus, maintaining adequate soil moisture levels in outdoor conditions is much more of a challenge, due to weather factors beyond the grower's control. Soil moisture levels are increased either by natural means (rainfall) or artificially via irrigation. Moisture losses occur primarily through the evaporation of water from the upper soil layers through the loss of water through leaf surfaces and other plant parts (transpiration). The rate of water loss as a result of transpiration is primarily dependent upon weather (i.e., temperature and humidity). Thus, growers must seasonally adjust their crop schedules according to the water intake and loss responses of the plants being grown.

Data Summary (Use additional pages)

Course: Agriscience Foundations I

Lesson: Propagating Plants Sexually (06.03.IL)

Objectives:

1. Explain sexual reproduction of plants and its importance in plant survival.
2. Explain how pollination occurs and describe the different types of pollination.
3. Explain fertilization in flowering plants.
4. Explain the structures and formation of seeds.
5. Describe the conditions for seed germination.
6. Compare and contrast indoor and outdoor growing conditions.

Student Performance Standards Addressed:

06.03: Propagate plants through sexual and asexual means.

Equipment, Supplies, References, and Other Resources:

References:

- Cooper, Elmer L. *Agriscience Fundamentals and Applications*, Third Edition. Albany, New York: Delmar Publishers, Inc., 2004.
- Lee, Jasper S. and Diana L. Turner. *AgriScience,* Third Edition. Danville, Illinois: Interstate Publishers, Inc., 2003.

Handouts:

- LS: 06.03.A.IL Environmental Factors Affecting Germination Student Handout
- LS: 06.03.B.IL Salinity and Seed Germination Student Handout
- “The Experimentation Process” handout

Video:

- Teaching Demonstration

Computer and video projection equipment:

- PowerPoint presentation or overhead projector
    - TM: 06.03a.A Pollination of a Flower
    - TM: 06.03a.B Fertilization of a Flower
    - TM: 06.03a.C Parts of a Bean Seed and a Corn Seed
    - TM: 06.03a.D Environmental Factors Necessary for Germination

Equipment & Supplies:

- Examples of perfect flowers (Interest Approach)
- See materials list on lab sheets
- Audio recorder
- Audio tapes

Teacher Directions	Content Outline and/or Procedures
REVIEW	***Push "record" on audio recorder*** Quickly review the objectives of Lesson 06.02.IL Determining the Importance of Photosynthesis and Respiration.
INTEREST APPROACH	Bring a couple of samples of perfect flowers, such as from a Hibiscus or a Lily plant, to class. Use them to show the students the various parts of a flower. Dissect the flower and demonstrate to students how the pollen gets from the anther to the stigma and then grows a pollen tube down through the style to fertilize the egg. Students should be able to see how the various parts of the flower interact for pollination to occur.
OBJECTIVES	
1. Explain sexual reproduction of plants and its importance in plant survival.	I. Sexual reproduction involves flowers, fruits, and seeds. A. In sexual reproduction, sperm carried in the pollen from the male flower fuses with the egg in the female part of the flower. Both contribute to the genetic makeup of the new plant. B. Each time sexual reproduction occurs, there is a recombining of genetic material. As a result, some changes will occur. Some may be beneficial and some may not. As conditions of the environment change over time, the beneficial changes in plant genetics will allow the plant to survive. As plants continue to reproduce, they pass genes onto their offspring, which enables them to survive.
2. Explain how pollination occurs and describe the different types of pollination. TM: 06.03a.A Pollination of a Flower	II. Pollination is the transfer of pollen from the male to the female part of a plant. A. Pollination occurs in many different ways: 1. Birds, insects, bats, and other animals are attracted to colorful, scented flowers. As they visit various flowers for food, they unintentionally pick up pollen and carry it from flower to flower. 2. Wind moves pollen from one flower to another. Plants that rely on wind generally do not produce colorful flowers with scents or nectar. B. Pollination of plants may occur in one of two ways:

Teacher Directions	Content Outline and/or Procedures
	1. Self-pollination occurs when pollen from a plant pollinates a flower on the same plant. 2. Cross-pollination occurs when pollen from a plant pollinates a flower on a different plant. C. Once pollen lands on the stigma, it grows a pollen tube down the style to the ovary. The cell within the grain of pollen divides to form two sperm nuclei, which travel down the pollen tube to the embryo sac, fertilizing the egg.
3. Explain fertilization in flowering plants. TM: 06.03a.B Fertilization of a Flower	III. Fertilization is necessary in flowering plants in order for the seed to develop. A. Fertilization in flowering plants is different from fertilization in any other living organism. In plants, both sperm nuclei in the pollen grain are involved in fertilization, resulting in a double fertilization. 1. The first fertilization occurs when one sperm fuses with the egg, resulting in a zygote. The resulting seed contains genetic information from both the male and female part of the flower. 2. The second fertilization occurs when the second sperm nucleus fuses with the two nuclei in the embryo sac. This will develop into the endosperm. The ovule of the flower will become the seed. B. When fertilization occurs and the parents are genetically different, the resulting offspring is said to be a hybrid. The advantage of hybrids is that the best traits of each parent, such as more vigorous growth, insect and disease resistance, or uniformity, may be expressed in the offspring. C. Genetic information is stored in every cell of a plant in long molecular chains made of Deoxyribonucleic acid (DNA). Segments of DNA, called genes, establish the code for life processes and the appearance of a plant. The genes are arranged in a set of chromosomes. Normal cells contain a double set of chromosomes and are said to be diploid. Reproductive cells, sperm and egg cells, have a single set of chromosomes and are said to be haploid. When fertilization occurs, the single sets of chromosomes are combined into the double set, one from each parent, resulting in traits from each parent being passed on to the offspring.

Teacher Directions	Content Outline and/or Procedures
4. Explain the structures and formation of seeds. TM: 06.03a.C Parts of a Bean Seed and a Corn Seed.	IV. The function of the seed is to grow and develop into a mature plant that will produce more seeds. A. Seeds of flowering plants have several parts. 1. The seed coat is a protective shell surrounding the embryo and endosperm. It protects the seed from drying and from physical injury. The seed coat helps in determining when conditions for germination or the beginning of growth are right. 2. The embryo is a little plant that eventually grows and develops into the mature plant. It remains dormant within the seed. It has a stem, root, and one or two seed leaves called cotyledons. Monocot embryos have one seed leaf and dicot embryos have two seed leaves. 3. The endosperm is the food storage tissue in the seed, particularly in monocots. Dicots store their food in the two cotyledons. The food storage is necessary for the young seedling until it is able to manufacture its own food. B. After fertilization, the ovary wall enlarges and forms the fruit. The fruit may be fleshy or dry. 1. Fleshy fruit prevents the seeds from drying until they are mature. They also serve to help disperse the seeds. Animals are attracted to fruit, eat it with the seeds, and disperse or disseminate the seeds somewhere away from the parent plant. Examples of fleshy fruit include tomatoes, apples, pears, etc. 2. Dry fruit is found on plants such as the dandelion and maple trees. It does not depend on animals for dissemination, but may depend on wind or other methods of dissemination.
5. Describe the conditions for seed germination. TM: 06.03a.D Environmental Factors Necessary for Germination	V. Seeds are designed to wait for favorable conditions to begin growth. They may lay dormant for many years before conditions allow them to begin to grow. A. Several environmental factors play key roles in seed germination. 1. Moisture or water is necessary for germination. 2. Air, particularly oxygen, is required for germination.

Teacher Directions	Content Outline and/or Procedures
	3. Warm temperatures, between 40 and 104 degrees F, are necessary for germination. 4. Some plants require light or total darkness for germination. B. Stratification is when the seed must go through a period of cold temperatures before it will germinate. C. Scarification is the breaking down of the seed coat. Some seeds have such a hard, thick seed coat that they prevent the absorption of water to enable germination to occur. D. The germination process begins with the absorption of water. The seed swells and the embryo changes from a dormant state to an actively growing plant. The embryo draws energy from starches stored in the endosperm or cotyledons. The embryo's root emerges from the seed and develops into the primary root. Then, the stem of the embryo sprouts upward. E. The quality of seed used is very important in production agriculture. Viable, or live, seed is important to ensure a high percentage of seed germination. Seed companies test seed to determine its germination percentage, which must be printed on the seed bag. Proper humidity and temperature during storage of the seeds help maintain seed viability. 5. High salt concentrations in the soil can have adverse effects on plant growth. A. Soil salinity is most severe in arid, irrigated areas around the world. Salinity may affect as much as 30% of all irrigated land in the U.S., primarily in the southwestern part of the country. B. In field conditions dissolved salts are usually applied in the irrigation water. Enough salt may accumulate in a few years to reduce the productivity of the soil. Standard practice in irrigation is to add enough water to permit some drainage to help remove salt buildup in the soil. Artificial drainage is a major investment. Research now underway is aimed at determining optimal amounts of irrigated water to apply, and developing simple methods of measuring soil salinity concentrations in the soil.

Teacher Directions	Content Outline and/or Procedures
	C. Salt buildup may also be a problem in greenhouse crops and indoor plants if drainage outlets are not provided in the growing container. Inadequate watering, even with well designed containers, can lead to salt buildup in the growing medium and eventual death of the plant.
6. Compare and contrast indoor and outdoor growing conditions.	VI. The grower has control over the quality and condition of seed, planting procedure, and weed competition, environmental conditions cannot be controlled in outdoor settings. The grower must be able to correctly interpret planting conditions and adjust timing and planting procedures accordingly. A. A major advantage of growing plants in greenhouses is that critical environmental conditions of moisture, temperature, oxygen and light can accurately be controlled. Control and/or correct adaptation to environmental conditions enhance overall seed germination and seedling establishment. Germination percentage affects plant population, which in turn affects profit potential of a given crop. B. In outdoor settings soil and seedbed conditions have a direct influence on moisture and oxygen availability for seed germination in vegetable, agronomic and horticulture crops. In addition, all plants have soil temperature ranges that will promote acceptable germination rates. Thus, growers must know the temperature ranges for their crops and time their plantings accordingly in order to ensure good germination and seedling establishment.
REVIEW/SUMMARY	Use the student learning objectives to summarize the lesson. Have students explain the content associated with each objective. Student responses can be used in determining which objectives need to be reviewed or taught from a different perspective. Questions at the end of chapters of textbooks covering this material may also be used in the review/summary. Complete Propagating Plants Sexually Worksheet.
APPLICATION	Complete LS: 06.03.A.IL Environmental Factors Affecting Germination and LS: 06.03.B.IL Salinity and Seed Germination

LS: 06.03.A.IL **Teacher Instructions**

Environmental Factors Affecting Germination

Interest Approach: ***(Present as follows.)***

Bring to class samples of a variety of seeds, including lettuce, marigold, grass, wheat and others. Ask students what conditions would be best for planting these seeds. Do all of these types of seed need the same conditions for optimal germination? If not, what are the unique requirements of each? Have one or more students plant some seeds in a flat or pot and then ask students to describe the ideal germination conditions for that seed type. Challenge their procedures (to maintain uncertainty in their minds about whether they have enough knowledge and skill to perform this task correctly).

Agriscience Applications: ***(Discuss.)***

While the grower has control over the quality and condition of seed, planting procedure, and weed competition, environmental conditions cannot be controlled in outdoor settings. The grower must be able to correctly interpret planting conditions and adjust timing and planting procedures accordingly. A major advantage of growing plants in greenhouses is that critical environmental conditions of moisture, temperature, oxygen and light can accurately be controlled. Control and/or correct adaptation to environmental conditions enhance overall seed germination and seedling establishment. Germination percentage affects plant population, which in turn affects profit potential of a given crop.

In outdoor settings soil and seedbed conditions have a direct influence on moisture and oxygen availability for seed germination in vegetable, agronomic and horticulture crops. In addition, all plants have soil temperature ranges that will promote acceptable germination rates. Thus, growers must know the temperature ranges for their crops and time their plantings accordingly in order to ensure good germination and seedling establishment.

!!Teacher note: Do NOT present the research problem to the students. Instead, challenge them to phrase the research question themselves.

Research Problem:

How do light, oxygen, temperature and moisture affect seed germination?

Purpose: ***(Present to class and discuss.)***

The purpose of this set of experiments is to examine the effects of the environmental conditions of light, oxygen, temperature, and moisture on seed germination. Optimal environmental conditions for selected plants will be generally determined. Through these experiments, students will be able to :

1. explain the effects of light, water, temperature, and oxygen on seed germination and why each of these elements is essential for germination; and
2. explain and/or develop recommended practices for planting selected vegetable, agronomic, and horticultural crops in terms of the germination process.

!!Teacher note: Pass out a copy of "The Experimentation Process" handout to each student. Have students work in lab groups to plan the design of their experiment by following the steps in this handout. Their written responses to each step in the experimentation process will constitute their design for this experiment. Allow groups to use different designs for their experiments as materials, time, and other resources allow. Require each group to develop a written design for their experiment **BEFORE** ***they proceed with conducting the experiment.***

!!Teacher note: Do NOT give the materials list and procedures to students. Instead, use them as a guide as you help students plan the design of their experiments.

Materials:

- lettuce or grass seeds
- bean seeds
- quart plastic bags (Ziplock)
- paper towels
- aluminum foil
- steel wool
- 2 jars with air-tight lids (pint or quart size)
- incubator or similar source for heat
- refrigerator
- eight 6 inch pots with potting soil or other soil mixture
- water
- gravel
- graph paper

Procedures:
(4 students per group)

Effects of light on germination:

1. Divide 75 lettuce or grass seeds into three groups of 25.
2. Wet six paper towels and fold two at a time so that they will fit into the plastic bags. Place one set of folded towels in each of six plastic bags.
3. Place 25 lettuce/grass seeds on top of the paper towels in each of three plastic bags.
4. Wrap two of the lettuce/grass bags in aluminum foil to exclude light.
5. Place all bags in the same place under moderate conditions of light and room temperature.
6. After one day, unwrap the foil from one group of seeds and expose to light for one hour. Then re-cover with foil and label as to light exposure conditions.

7. Count the number of seeds that germinate after two and four days in each of the three bags. Record data and calculate the rate of germination. Graph results ***(Be sure students have properly identified the independent and dependent variables and that the graphs are labeled appropriately.)***

Effects of oxygen on germination:

1. Soak 20 bean seeds in water for 12 hours.
2. Obtain two jars with tight-fitting lids and line the sides with paper towels.
3. Loosely stuff paper towels into one jar to keep the lining pressed to the sides.
4. Loosely stuff paper towels and steel wool pads into the center of the other jar.
5. Evenly space ten bean seeds between the paper towels and wall of each jar.
6. Wet the contents of both jars leaving approximately two to three cm. of water in the bottom of each jar.
7. Tightly seal each jar.
8. Observe the bean seeds daily for seven to ten days.
9. Observe the steel wool after seven to ten days and record your observations. Graph results ***(Be sure students have properly identified the independent and dependent variables and that the graphs are labeled appropriately.)***

Effects of temperature on germination:

1. Divide 75 bean seeds into three groups of 25.
2. Evenly space 25 seeds on top to two layers of moistened paper towels. Cover the seeds with two more layers of moistened paper towels.
3. Fold over the edges of the towels and roll up the towels and enclosed seeds into a tube (called a rag doll). Secure each end with a rubber band. Repeat this procedure until two more rag dolls are made.
4. Label each plastic bag with where the seed will be placed: cold, warm, control (room temperature). Put one rag doll in each bag and seal.
5. Place the bags in the assigned environment, positioning the rag dolls in an upright position:
   Warm environment- Use an incubator or heat source which will keep the seeds at approximately 85-90° F.
   Control- Room temperature 68-76° F.
   Cold environment- Place seeds in the refrigerator (35-40° F).
6. Record the number of seeds germinated at days 3, 5, and 7 for each treatment group and calculate the final germination percentage at day seven. Graph results ***(Be sure students have properly identified the independent and dependent variables and that the graphs are labeled appropriately.)***
7. Combine individual student data to obtain class average.

Effects of moisture on germination:

1. Divide 80 bean seeds into equal groups of 10. Place a small amount of gravel in the bottom of eight 6-inch pots. Then fill with potting soil or another soil mixture to within one inch of the top of the pot. Slowly pour one liter of tap water into each pot and allow to drain well by tipping and shaking pot.
2. Plant ten seeds 1 cm deep in each of four pots and label. Plant ten seeds 4 cm deep in the other four pots and label accordingly.
3. Four different watering patterns will be tested for each of the two planting depths. Label one pot from each planting depth group as follows: no additional water; 80 ml on day 5; 40 ml on days 2, 4, 6, and 8; and 40 ml every day. Place pots in a sunny location, maintaining a temperature of at least 70 degrees F.
4. Add water as indicated by the treatment group for the next 9 days.
5. Record the number of seeds germinated in each pot on days 4, 7, and 10. Calculate the germination percentage. Graph results ***(Be sure students have properly identified the independent and dependent variables and that the graphs are labeled appropriately.)***

Anticipated Findings:

Actual numbers of seeds that germinate will vary, but greater exposure to light should be accompanied by greater germination of the lettuce/grass seeds and less germination by the onion sets. Seeds in oxygen-rich environments will germinate better. Seeds stored in the warmest temperatures should germinate the quickest and yield the highest percentage of germination. Moisture and seed depth will also have optimum levels.

!!Teacher note: Do NOT give the students sample formats for data summary tables. Instead challenge them to develop formats themselves and use the sample provided to guide your supervision of their work.

Data Summary:

Observations should be taken in each of the four experiments as specified and the number of germinated seeds recorded. Have students complete simple data summary tables for each experiment. Students should graph the germination percentages in the moisture experiment by treatment group and number of days. In addition, students should observe and record the quality/healthiness of seedlings in the temperature, oxygen, and moisture experiments.

Sample Data Summary Tables

Effect of Light on Germination

Treatment	Germination			
	2 Days		4 Days	
	#	%	#	%
No Light				
Limited Light (1 hour)				
Constant Light				

Effects of Oxygen on Germination

Day	Bean Seed Observation
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Steel Wool Observation after 7 – 10 days

Effects of Temperature on Germination

Day	Cold		Room Temp.		Warm	
	#	%	#	%	#	%
3						
5						
7						

Effects of Moisture on Germination

Treatment	Germination											
	1 cm Deep						4 cm Deep					
	Day 4		Day 7		Day 10		Day 4		Day 7		Day 10	
	#	%	#	%	#	%	#	%	#	%	#	%
No additional water												
80 ml on day 5												
40 ml on days 2, 4, 6, and 8												
40 ml every day												

!!Teacher note: Challenge your students to first identify in writing their conclusions, then use the following list to verify and modify their ideas.

Conclusions: ***(Lead a discussion of these and other conclusions.)***
1. Some seeds need light to germinate.
2. Seeds need oxygen to germinate.
3. Warmer temperatures increase germination for most seeds.
4. Seeds need moisture to germinate.
5. Optimum levels of moisture, temperature, and planting depth exist.

Discussion:
(Use a supervised study session or whole class discussion to answer the following questions.)
1. What were the most difficult aspects of conducting this experiment?
2. Did the experimental procedures produce the desired results? (Were you able to answer your research question?)
3. What would you do differently in conducting this experiment a second time?
4. Why do some seeds need light to germinate?
5. Why is moisture needed for germination?
6. Why is good seed to soil contact needed for successful germination?
7. What happens if seeds are planted too deeply? Why?
8. Why is oxygen needed for seed germination?
9. Are viable seeds alive? Explain.
10. Why don't most seeds need light to germinate, since light is necessary for photosynthesis?
11. What happens inside a seed to cause it to germinate?
12. Why did the seeds inside the jar with steel wool germinate poorly?

13. Why do cold temperatures slow or stall germination?

!!Teacher note: Do NOT give the following ideas to your students. Instead, challenge them to identify their own ideas for further experimentation. Then lead a class discussion on how such experiments could be designed to answer their research objectives.

Further Investigation:

(Lead a discussion of these and other ideas.)

1. Compare the impact of these environmental factors for a variety of seed types.
2. Vary the amount of light in the first experiment to determine how much light per day is optimal for seeds that require light for germination.

!!Teacher note: Have each student or lab group select one of the ideas for further investigation and describe in writing the design for that experiment. (Address each step of the experimentation process – see handout.)

LS: 06.03.A.IL **Student Handout**

ENVIRONMENTAL FACTORS AFFECTING GERMINATION

Purpose and Objectives of Lab:

The purpose of this set of experiments is to examine the effects of the environmental conditions of light, oxygen, temperature, and moisture on seed germination. Optimal environmental conditions for selected plants will be generally determined. Through these experiments, students will be able to :

1. explain the effects of light, water, temperature, and oxygen on seed germination and why each of these elements is essential for germination; and
2. explain and/or develop recommended practices for planting selected vegetable, agronomic, and horticultural crops in terms of the germination process.

Research Problem:

Your hypothesis is:

Materials: (Use additional pages if needed.)

Procedures: (Use additional pages if needed.)

Effects of light on germination:

Effects of oxygen on germination:

Effects of temperature on germination:

Effects of moisture on germination:

Agriscience Applications:

While the grower has control over the quality and condition of seed, planting procedure, and weed competition; environmental conditions cannot be controlled in outdoor settings. The grower must be able to correctly interpret planting conditions and adjust timing and planting procedures accordingly. A major advantage of growing plants in greenhouses is that critical environmental conditions of moisture, temperature, oxygen and light can accurately be controlled. Control and /or correct adaptation to environmental conditions enhance overall seed germination and seedling establishment. Germination percentage affects plant population, which in turn affects profit potential of a given crop.

In outdoor settings soil and seedbed conditions have a direct influence on moisture and oxygen availability for seed germination in vegetable, agronomic and horticulture crops. In addition, all plants have soil temperature ranges that will promote acceptable germination rates. Thus, growers must know the temperature ranges for their crops and time their plantings accordingly in order to ensure good germination and seedling establishment.

Data Summary (Use additional pages if needed.)

LS: 06.03.B.IL **Teacher Instructions**

Salinity and Seed Germination

Interest Approach: ***(Present as follows.)***

Ask students to identify areas in Florida, the United States and around the world where field crops are irrigated. In what geographical areas does irrigated water provide essentially the only water received by the crop during a growing season? How do irrigated water and rain water differ? Which is better for plants? Why? Steer students in the direction of salt buildup in irrigated soils. Why does this occur? What effects does it have on crops? Why? Is this also a problem with container plants? Why or why not?

As an alternative, bring a potted plant to class. Tell students you accidentally spilled some table salt onto the soil of a potted plant. Will this harm the plant? Why? Can the salt be washed out of the soil? Tie this into salt buildup in irrigated soils as described above. Continue to care for the plant in the usual way and let students observe the effects of the salt on the plant.

Agriscience Applications: ***(Discuss.)***

High salt concentrations in the soil can have adverse effects on plant growth. Although plants require certain salt constituents for growth, some soils contain such large quantities of soluble salts that crop yields are decreased. Soil salinity is most severe in arid, irrigated areas around the world. Salinity may affect as much as 30% of all irrigated land in the U.S., primarily in the southwestern part of the country. A wide variety of major agronomic and horticultural crops are grown in this region of the United States.

In field conditions dissolved salts are usually applied in the irrigation water. Enough salt may accumulate in a few years to reduce the productivity of the soil. Current standard practice in irrigation is to add enough water to permit some drainage to help remove salt buildup in the soil. Artificial drainage is a major investment. Research now underway is aimed at determining optimal amounts of irrigated water to apply, and developing simple methods of measuring soil salinity concentrations in the soil.

Salt buildup may also be a problem in greenhouse crops and indoor plants if drainage outlets are not provided in the growing container. Inadequate watering, even with well designed containers, can lead to salt buildup in the growing medium and eventual death of the plant.

!!Teacher note: Do NOT present the research problem to the students. Instead, challenge them to phrase the research question themselves.

Research Problem:

What are the effects of salt buildup in soils on seed germination and plant growth?

Purpose of Lab: ***(Present to class and discuss.)***

The purpose of this experiment is to determine the effects of salt accumulation in soils on seed germination and plant growth. By participating in this lab, students will be able to:

1. explain the causes of soil salinity;
2. describe the general effects of salt accumulation in soils on plant growth and development; and
3. explain why/how excessive salt concentrations in soil water have harmful effects on plants.

!!Teacher note: Pass out a copy of "The Experimentation Process" handout to each student. Have students work in lab groups to plan the design of their experiment by following the steps in this handout. Their written responses to each step in the experimentation process will constitute their design for this experiment. Allow groups to use different designs for their experiments as materials, time, and other resources allow. Require each group to develop a written design for their experiment BEFORE they proceed with conducting the experiment.

!!Teacher note: Do NOT give the materials list and procedures to students. Instead, use them as a guide as you help students plan the design of their experiments.

Materials:

- twelve 6" pots with drainage holes
- 20 lb. bag of potting soil
- 30 seeds each of peas, green beans, and sweet corn
- four 2-liter containers with lids or caps
- table salt
- gravel
- 50 ml beaker
- balance
- graph paper

Procedures:
(4 students per group)

1. Place about 2 cm of gravel in the bottom of each of 12 pots. Then add about 9 cm of potting soil to each pot so the soil line is about 3 cm from the top of the pot.
2. Add one liter of tap water to each pot and allow to drain well by tipping and shaking.
3. Make 4 irrigation solutions by adding 36g of NaCl (table salt) to container #4, 24g to container #3, 12g to container #2, and no salt to container #1. Fill each container with 2 liters of tap water.
4. Plant 10 green bean seeds 2 cm deep in each of 4 pots. Plant 4 pots of sweet corn and 4 pots of peas in the same manner.
5. Label all pots with seed type and 1 through 4 for irrigation solution.

6. Place the pots in a sunny location and keep moist (but not wet) by adding about 40 ml of the proper irrigation solution to each pot, preferably once a day in late morning. Seedlings should appear in 5 to 7 days.
7. Record the number of seeds germinated at days 3, 5, 7, 9, 11, 13, and 15 for each treatment group and calculate the final germination percentage at day fifteen. Graph results ***(Be sure students have properly identified the independent and dependent variables and that the graphs are labeled appropriately.)***
8. Combine individual student data to obtain class average.

Anticipated Findings:

The extent of the salinity effect depends upon plant species and even variety. Sensitivity to salinity also varies with stage of growth, with younger plants being more sensitive. Pots receiving the highest concentrations of salt in the irrigation water will have reduced germination rates and slower seedling growth rates. Results will vary, so multiple tests should be done simultaneously. Several days after germination, seedlings will begin to show signs of salt damage, which include curling up and dampening off of leaves. Some seeds will be unable to complete the germination process. In general, peas will be more resistant to salt concentrations, while progressive effects will be seen with green beans as the salt concentrations become higher.

!!Teacher note: Do NOT give the students sample formats for data summary tables. Instead challenge them to develop formats themselves and use the sample provided to guide your supervision of their work.

Data Summary:

Record the number of seeds germinated on days 5, 7, 9, 11, 13, and 15. Keep watering and record data until one plant reaches the height of about 15 cm. Record all plant heights at that time. Have students use tables to summarize the data (see example that follows). At day 15 calculate average plant height for germinated seeds in each pot. Divide average plant height in pots 2, 3, and 4 by plant height in pot 1 to determine a ratio, based on the control.

Plot for each seed type the number of seeds germinated as a function of time for each salinity level. Also plot percentage germination after 15 days by salinity level for each type of seed.

Sample Data Summary Table
Number of Seeds Germinated by Seed Type and Salt Concentration

	Irrig. Solu. #1	Irrig. Solu. #2	Irrig. Solu. #3	Irrig. Solu. #4
Day 3				
peas				
corn				
beans				
Day 5				
peas				
corn				
beans				
Day 7				
peas				
corn				
beans				
Day 9				
peas				
corn				
beans				
Day 11				
peas				
corn				
beans				
Day 13				
peas				
corn				
beans				
Day 15				
peas				
corn				
beans				

!!Teacher note: Challenge your students to first identify in writing their conclusions, then use the following list to verify and modify their ideas.

Conclusions: ***(Lead a discussion of these and other conclusions.)***

1. Salt accumulation in the soil decreases seed germination. Higher salt concentrations are associated with increased seed and plant injury.
2. Salt buildup negatively affects plant growth and causes plants to weaken and sometimes die.

Discussion:

(Use a supervised study session or whole class discussion to answer the following questions.)

1 What were the most difficult aspects of conducting this experiment?
2. Did the experimental procedures produce the desired results? (Were you able to determine the effects of salt concentrations in the soil on seed germination and plant growth?)
3. What would you do differently in conducting this experiment a second time?
4. What causes salt accumulation in soils and growing media?
5. What practices do growers use to reduce salt buildup in soils? How do these practices work to lower salt accumulations?
6. What factors affect soil salinity?
7. What are the sources of salts that can accumulate in soils?
8. Why/how does salt in the soil solution affect seed viability and germination?
9. How is salt buildup in soils related to plant transpiration?

!!Teacher note: Do NOT give the following ideas to your students. Instead, challenge them to identify their own ideas for further experimentation. Then lead a class discussion on how such experiments could be designed to answer their research objectives.

Further Investigations: ***(Lead a discussion of these and other ideas.)***

1. Use a variety of seed types, both agronomic and vegetable, to determine the differential effects of soil salinity on germination and seedling growth.
2. Use a combination of salt concentrations in the irrigation solution. Higher concentration will yield more dramatic results.
3. Use different soil types to examine the buffering effects of soil type on soil salinity and corresponding plant growth.
4. Test the degree of tolerance of various plants species to salts. Field crops, vegetable and house plants can be examined.

!!Teacher note: Have each student or lab group select one of the ideas for further investigation and describe in writing the design for that experiment. (Address each step of the experimentation process – see handout.)

LS: 06.03.B.IL **Student Handout**

Salinity and Seed Germination

Purpose of Lab:

The purpose of this experiment is to determine the effects of soil accumulation in soils on seed germination and plant growth. By participating in this lab, students will be able to:

1. explain the cause of soil salinity;
2. describe the general effects of salt accumulation in soils on plant growth and development; and
3. explain why/how excessive salt concentrations in soil water have harmful effects on plants.

Research Problem:

Your hypothesis is:

Materials: (Use additional pages if needed.)

Procedures: (Use additional pages if needed.)

Agriscience Applications:

High soil water concentrations can have adverse effects on plant growth. Although plants require certain salt constituents for growth, some soils contain such large quantities of soluble salts that crop yields are decreased. Soil salinity is most severe in arid, irrigated areas around the world. Salinity may affect as much as 30% of all irrigated land in the U.S., primarily in the southwestern part of the country. A wide variety of major agronomic and horticultural crops are grown in this region of the United States.

In field conditions dissolved salts are usually applied in the irrigation water. Enough salt may accumulate in a few years to reduce the productivity of the soil. Current standard practice in irrigation is to add enough water to permit some drainage to help remove salt buildup in the soil. Artificial drainage is a major investment. Research now underway is aimed at determining optimal amounts of irrigated water to apply, developing simple methods of measuring soil salinity concentrations in the soil.

Salt buildup may also be a problem in greenhouse crops and indoor plants if drainage outlets are not provided in the growing container. Inadequate watering, even with well designed containers, can also lead to salt buildup in the growing medium and eventual death of the plant.

Data Summary (Use additional pages if needed.)

APPENDIX C
CONTENT KNOWLEDGE PRETEST

Instructions on completing the answer sheet:

1. Enter your name in the spaces provided. (Last Name, First Initial, Middle Initial)
2. Darken the appropriate circle under each letter of your name.
3. In the section titled "ID No." enter the individual code number given to you by your teacher in the first five spaces. (This will be a five digit number.)
4. Darken the appropriate circle under each number of the individual code.
5. Leave the sections titled "Section" and "Special Codes" blank.
6. In the Test Form Code section, darken the circle corresponding to the Test Form code found on the top of this exam.

Directions: Read the questions completely and carefully, then darken the circle on the answer sheet that corresponds to the best answer for each of the following questions.

1. Greenhouses offer more control than crops grown in field conditions over which of the following variables?
   a. machinery costs
   b. environmental conditions
   c. labor
   d. all variables

2. You observe two plants of the same species. You are told that one plant is the "daughter" of the other. You observe that the "daughter" plant has a slightly different leaf structure. With this information you can hypothesize that the "daughter" plant was produced through which propagation method?
   a. sexual propagation
   b. asexual propagation

3. What is the standard industry test for determining seed viability?
   a. TZ test
   b. warm germination test
   c. cold germination test
   d. excised embryo test

4.For most grass seeds, how will additional light during germination affect germination rate?
   a. decrease
   b. increase
   c. not affect

5. Seeds that you planted several weeks ago still haven't germinated. In reexamining your seeds you observe that pots containing your seeds were flooded with water. What factor is most likely the cause for the seeds not germinating?
   a. low temperature
   b. lack of fertility
   c. lack of moisture
   d. lack of oxygen

6. How does gibberellic acid affects seed germination rates?
   a. increasing the response to plant toxins
   b. increasing the concentration of soil moisture
   c. increasing cell division

7. When seeds are planted too deeply, why is germination rate reduced?
   a. a fungus often develops due to excessive moisture
   b. sunlight is not available
   c. seed rot occurs
   d. food reserves are used up before roots can begin nutrient uptake

8. Seed germination involves the action of enzymes which:
   a. convert starch into sugar
   b. convert starch into amino acids
   c. convert starch to gibberellic acid

9. Which part of a seed is actually a plant in an arrested state of development?
   a. endosperm
   b. plantlet
   c. embryo

10. In general, as soil temperature decreases, what will happen to germination rate?
   a. is unaffected
   b. decreases
   c. increases

11. What causes seed swelling at the beginning of germination?
   a. embryonic growth
   b. water intake
   c. cell division
   d. enzymatic activity

12. Why are wet, compacted soils likely to result in lower germination rates?
    a. increased oxygen
    b. increased water
    c. decreased oxygen

13. What is commonly the cause of salt buildup in soils?
    a. under-fertilization
    b. overwatering
    c. use of pesticides
    d. inadequate watering

14. In which of the following states is soil salinity of most concern?
    a. Arizona
    b. Tennessee
    c. Kansas
    d. Ohio

15. Why are well drained soils less likely to suffer from salt buildup?
    a. water moves rapidly downward through the soil, leaving salts on the soil surface
    b. water runoff is greater
    c. water moving downward through the soil carries salts with it
    d. water evaporates from the soil surface more quickly

16. What would you expect for a plant that is grown in direct sun, given adequate amounts of fertilizer and water?
    a. evaporation to be low
    b. transpiration to be high
    c. photosynthesis to be low

17. Why shouldn't germinating seeds come in contact with fertilizers?
    a. salt has a negative effect on water intake
    b. seed rot is a greater concern
    c. excessive growth will occur
    d. the fertilizer will dissolve too quickly

18. A farmer lives in a salinity affected area. What would be the best strategy for him to get the most productive yields from his land?
    a. irrigate occasionally, especially when it is hot
    b. use a lot of chemicals on his fields to dissolve the soil
    c. use moldboard plowing
    d. plant salt-tolerant plant varieties

19. What is water loss through plant tissues called?
    a. dehydration
    b. evaporation
    c. transpiration

20. Where does water loss in plant tissues primarily occur?
    a. leaves
    b. stems
    c. flowers
    d. roots

21. When managing a greenhouse, how should you water?
    a. to incorporate nutrient solutions
    b. to keep soils wet
    c. to avoid extremes in water availability
    d. to replenish dry soils

22. Approximately what percentage of all water absorbed by a plant's root system is given off through plant tissues?
    a. 49%
    b. 67%
    c. 90%
    d. 99%

23. What are the tiny pores through which water vapor escapes from the plant tissue called?
    a. micropores
    b. stomata
    c. macropores
    d. xylem

24. As water is lost from plant tissues, differences in which variable creates a suction effect that pulls more water into the plant through the root system?
    a. osmotic pressure
    b. tissue thickness
    c. humidity
    d. air pressure

25. Plants lose their ______ as water content decreases in plant cells .
    a. leaves
    b. vigor
    c. turgidity
    d. phloem

26. Which plant has the highest rate of transpiration?
    a. a small plant in a bedroom
    b. a large plant in a garden
    c. a small plant in a garden
    d. a large plant on a porch

27. In general, what happens to the amount of water loss through the plant tissue as the temperature drops on a cool, fall day?
    a. decreases
    b. cycles up and down
    c. remains constant
    d. increases

28. On a warm, sunny day with a slight breeze, the loss of water through the plant tissues will be:
    a. increased by the breeze due to lower humidity around the plant tissues
    b. unaffected by the breeze
    c. decreased by the breeze due to higher humidity around the plant tissues
    d. increased by the breeze due to movement of the plant tissues

29. The loss of water through the tissues of most plants:
    a. occurs during lighted, warmer times of the day
    b. is unrelated to processes in the plant
    c. occurs at the same rate throughout the day and night
    d. occurs during the dark, cooler hours only

30. What occurs when water is lost through plant tissues at a faster rate than water can be absorbed by the root system?
    a. wilting
    b. growth
    c. symbiosis
    d. photosynthesis

31. What is formed by groups of cells that are alike in activity and structure?
    a. Nucleus
    b. Organ
    c. Tissue

32. What is the movement of water from greater concentration in the soil to lower concentration in the root is called?
    a. absorption
    b. osmosis
    c. intake

33. Which of the following is NOT a component of the process of photosynthesis?
    a. nitrogen
    b. light
    c. carbon dioxide
    d. oxygen

34. What is the process by which an organism provides its cells with oxygen is called?
    a. photosynthesis
    b. light reaction
    c. transpiration
    d. respiration

35. Some seeds must go through a period of cold temperatures before they will germinate. What is this process called?
    a. stratification
    b. cold fusion
    c. scarification
    d. dormination

36. Which of the following provide the energy needed to power the Calvin cycle?
    a. ATP, carbon dioxide, and oxygen
    b. NADPH and ATP
    c. photosynthesis and ATP
    d. respiration and RuBP

37. Where does a young seedling gains the food it needs until it is able to manufacturer its own?
    a. embryo
    b. endosperm
    c. soil

38. What happens to a plant's transpiration rate as the amount of oxygen in the environment surrounding a plant decreases?
    a. decreases
    b. stays the same
    c. increases

39. Which of the following processes creates a pull that aids in the absorption of water by the roots?
    a. photosynthesis
    b. respiration
    c. transpiration
    d. cell division

40. Which of the following is NOT a function of plant roots?
    a. anchor plants
    b. produce food
    c. absorb water and minerals
    d. store food

41. Which of the following best describes the characteristics of a dicot plant?
    a. narrow leaves with parallel veins
    b. many small roots
    c. two seed leaves
    d. three or more leaves at each node

42. Which of the following conducts water up the stem and to the leaves?
    a. xylem
    b. roots
    c. phloem

43. After fertilization, the ovary wall enlarges and forms which part of the plant?
    a. seed
    b. style
    c. fruit

44. Which of the following is NOT a cell organelle?
    a. vacuole
    b. stolon
    c. mitochondria
    d. nucleolus

45. Which of the following plant part lists are in the order in which water enters a plant?
    a. leaf, stem, root
    b. root, xylem, leaf
    c. root, phloem, leaf
    d. leaf, xylem, root

46. What would be the best way to determine the effect temperature has on transpiration?
    a. Place a plant in a heated room. Measure the time it takes the plant to become wilted.
    b. Place two plants inside a jar of water. Measure the temperature and the amount of water that is lost from the jar.
    c. Place two plants in two separate jars of water. Place them at two different temperatures and seal the top of the jars. Record the amount of water that is lost from the jar.

47. In an experiment in which petroleum jelly is placed on the underside of some of the leaves of a plant, what would be the expected outcome?
    a. transpiration would increase
    b. photosynthesis would increase
    c. there would be no effect on the plant
    d. transpiration would decrease

48. Which of the following leaf arrangements has the highest transpiration rate?
    a. alternate
    b. opposite
    c. whorled
    d. leaf arrangement does not affect transpiration rate.

49. What is produced when water, carbon dioxide, and light energy are in the presence of a healthy green plant?
    a. complex sugar
    b. starch
    c. oxygen

50. How does the process of osmosis aid in plant nutrient uptake?
    a. water leaves the root until the pressure inside the root is less than the pressure outside the root
    b. water and nutrients are absorbed by the roots until the nutrient concentration is high.
    c. water moves from a greater concentration in the soil to a lower concentration in the root.

APPENDIX D
CONTENT KNOWLEDGE POSTTEST

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    d. nucleolus

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    c. root, phloem, leaf
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    a. embryo
    b. endosperm
    c. soil

49. What is produced when water, carbon dioxide, and light energy are in the presence of a healthy green plant?
    a. complex sugar
    b. starch
    c. oxygen

50. How does the process of osmosis aid in plant nutrient uptake?
    a. water leaves the root until the pressure inside the root is less than the pressure outside the root
    b. water and nutrients are absorbed by the roots until the nutrient concentration is high.
    c. water moves from a greater concentration in the soil to a lower concentration in the root.

APPENDIX E
ANSWER KEY TO CONTENT KNOWLEDGE INSTRUMENTS

Multiform Grid

Answer	Pretest	Posttest
D	1	4
A	2	1
B	3	40
C	4	3
D	5	5
C	6	6
D	7	16
A	8	7
C	9	8
B	10	18
B	11	9
C	12	11
D	13	12
A	14	13
C	15	44
B	16	15
A	17	42
D	18	17
C	19	19
A	20	20
D	21	21
D	22	22
B	23	31
A	24	23
C	25	24
B	26	26
A	27	27
A	28	28
A	29	29
A	30	30
C	31	32
B	32	33
A	33	25
A	34	34
A	35	35
B	36	36
B	37	48
A	38	37

Answer	Pretest	Posttest
C	39	38
B	40	39
A	41	14
A	42	41
C	43	43
B	44	45
B	45	46
C	46	47
D	47	2
D	48	10
C	49	49
C	50	50

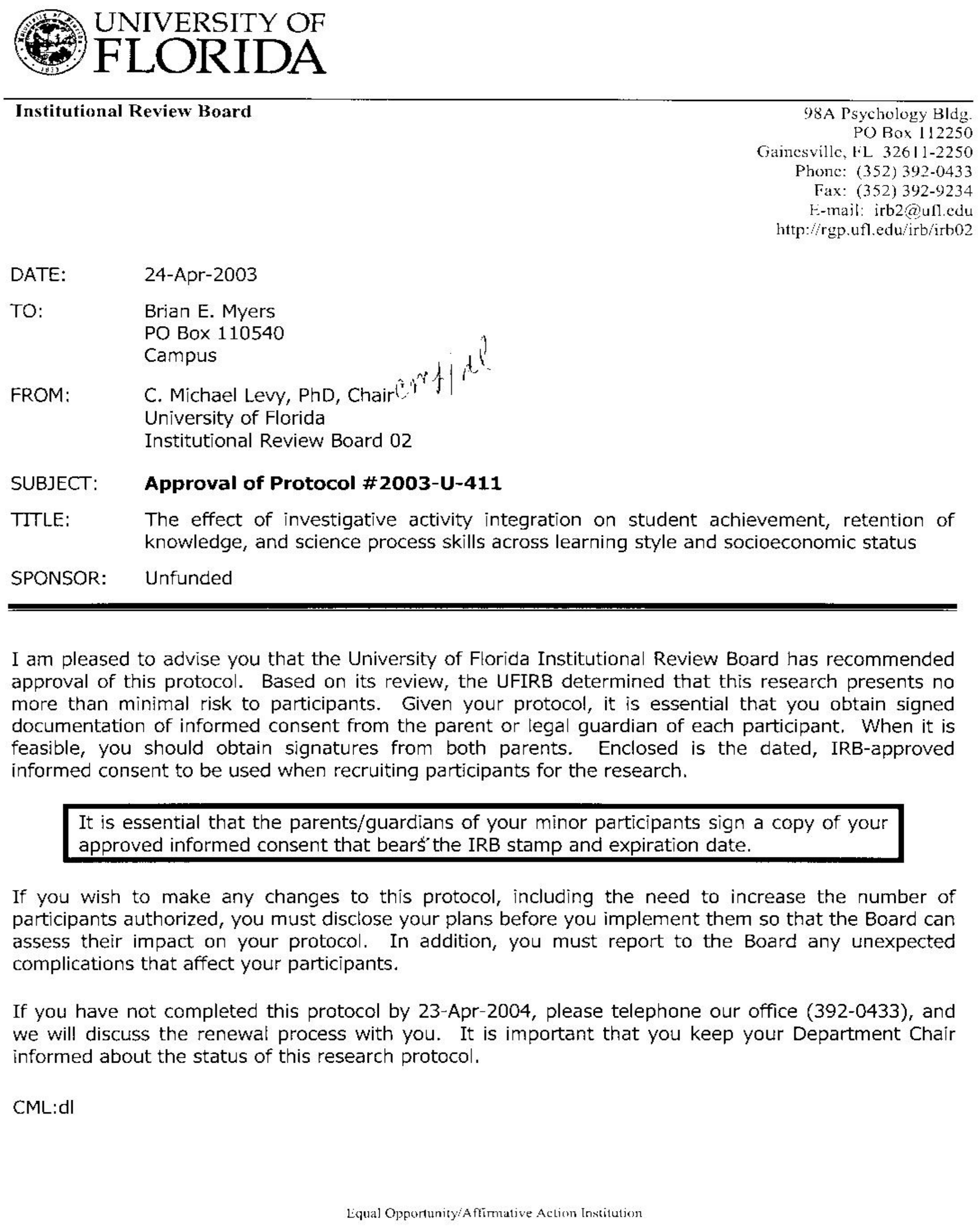
APPENDIX F
STUDENT DEMOGRAPHIC INFORMATION SHEET

DIRECTIONS: Please complete the following information for all students in the Agriscience Foundations class.

School ID: **XX**		Section ID: **X**		Total number of days lessons were taught:		
Student ID#	Name [a]	Grade	National School Lunch Program [b]	Ethnicity	Gender	Days Absent[c]
01		☐ 9 ☐ 11 ☐ 10 ☐ 12	☐ Does not participate ☐ Reduced lunch ☐ Free lunch	☐ Black ☐ White ☐ Hispanic ☐ Other	☐ Male ☐ Female	
02		☐ 9 ☐ 11 ☐ 10 ☐ 12	☐ Does not participate ☐ Reduced lunch ☐ Free lunch	☐ Black ☐ White ☐ Hispanic ☐ Other	☐ Male ☐ Female	
03		☐ 9 ☐ 11 ☐ 10 ☐ 12	☐ Does not participate ☐ Reduced lunch ☐ Free lunch	☐ Black ☐ White ☐ Hispanic ☐ Other	☐ Male ☐ Female	
04		☐ 9 ☐ 11 ☐ 10 ☐ 12	☐ Does not participate ☐ Reduced lunch ☐ Free lunch	☐ Black ☐ White ☐ Hispanic ☐ Other	☐ Male ☐ Female	
05		☐ 9 ☐ 11 ☐ 10 ☐ 12	☐ Does not participate ☐ Reduced lunch ☐ Free lunch	☐ Black ☐ White ☐ Hispanic ☐ Other	☐ Male ☐ Female	
06		☐ 9 ☐ 11 ☐ 10 ☐ 12	☐ Does not participate ☐ Reduced lunch ☐ Free lunch	☐ Black ☐ White ☐ Hispanic ☐ Other	☐ Male ☐ Female	

[a] The name column is included on this form for your school's use only. Please mark out the names of student when returning this form.
[b] This information will need to be obtained from your school's student services department.
[c] The number of days the student was absent when the lessons were being taught.

APPENDIX G
IRB APPROVAL



UNIVERSITY OF
FLORIDA

Institutional Review Board

98A Psychology Bldg.
PO Box 112250
Gainesville, FL 32611-2250
Phone: (352) 392-0433
Fax: (352) 392-9234
E-mail: irb2@ufl.edu
http://rgp.ufl.edu/irb/irb02

DATE: 24-Apr-2003

TO: Brian E. Myers
PO Box 110540
Campus

FROM: C. Michael Levy, PhD, Chair
University of Florida
Institutional Review Board 02

SUBJECT: **Approval of Protocol #2003-U-411**

TITLE: The effect of investigative activity integration on student achievement, retention of knowledge, and science process skills across learning style and socioeconomic status

SPONSOR: Unfunded

I am pleased to advise you that the University of Florida Institutional Review Board has recommended approval of this protocol. Based on its review, the UFIRB determined that this research presents no more than minimal risk to participants. Given your protocol, it is essential that you obtain signed documentation of informed consent from the parent or legal guardian of each participant. When it is feasible, you should obtain signatures from both parents. Enclosed is the dated, IRB-approved informed consent to be used when recruiting participants for the research.

It is essential that the parents/guardians of your minor participants sign a copy of your approved informed consent that bears the IRB stamp and expiration date.

If you wish to make any changes to this protocol, including the need to increase the number of participants authorized, you must disclose your plans before you implement them so that the Board can assess their impact on your protocol. In addition, you must report to the Board any unexpected complications that affect your participants.

If you have not completed this protocol by 23-Apr-2004, please telephone our office (392-0433), and we will discuss the renewal process with you. It is important that you keep your Department Chair informed about the status of this research protocol.

CML:dl

Equal Opportunity/Affirmative Action Institution

APPENDIX H
INITIAL EMAIL TO PARTICIPATING TEACHERS

Let me thank each of you again for agreeing to participate in the Agriscience Foundations project this fall. I just wanted to send out a quick e-mail to make sure the address that I have is correct and to provide you with some more introductory information.

Please let me know your school's start date. That way I can make sure to get the permission forms to you prior to the start of school. Also, if you know a time that will work best for me to stop by your school to drop off the project supplies please let me know that as well (late July - early August). I'm guessing we would need to schedule about two hours to visit about the project during my visit. Also, as soon as you know some firm numbers on your Agriscience Foundation class enrollment, let me know. Once I have that information, I can start to put together the packets for each school.

As you recall, the lessons should take 4-6 weeks to complete in your class. All lessons are part of a plant germination unit. Please look at your course calendar and let me know when you would like to teach these lessons. The only time restrictions are that the lessons need to be taught in a solid block and completed no later than mid-November.

There are a number of ways you can contact me. The easiest way is by e-mail. However, feel free to call me at any of the phone numbers listed below.

E-mail: bmyers@ufl.edu
Office: (352) 392-0502 ext. 223
Home: (352) 373-1773
Mobile: (352) 256-2457

Thank you again and please send me your school's start date, Agriscience Foundations enrolment numbers, and a preferred meeting time as soon as you can. I look forward to working with each of you on this project.

Brian

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APPENDIX I
OUTLINE FOR VIDEO TAPED TEACHER INSTRUCTIONS

Section I: General Information (Same for all three versions)

- I. Consent letters
  - A. Student
  - B. Parent/Guardian
  - C. Teacher
- II. Student Demographics Sheet
  - A. ID Number
  - B. Days of Instruction
  - C. Other information
    - 1. Work with Student Services Department
- III. Content Knowledge Exams
  - A. Forms A, B, & C
  - B. Completing the answer sheets
  - C. When to administer
  - D. How long will it take?
- IV. Science Process Skill Test
  - A. Forms A, B, & C
  - B. Completing the answer sheets
  - C. When to administer
  - D. How long will it take?
- V. Attitude Toward Instruction Survey
  - A. Forms A, B, & C
  - B. Completing the answer sheets
  - C. When to administer
  - D. How long will it take?

VI. Audio Tapes

- A. What to record
- B. Who reviews the tapes
- C. Why?

VII. Returning Materials

- A. Business reply envelops
- B. Band like items
- C. When

<u>Section II: Lesson Plans</u> (Three different versions – SM, PL, IL)

I. Description of assigned teaching technique

II. Lesson Plan Format

- A. Objectives
- B. SPS
- C. Equipment, supplies, etc.
- D. Content
  - 1. Transparencies
  - 2. Handouts

- E. Review/summary
  - 1. Worksheet

- F. Applications (Only for PL and IL versions)
  - 1. Lab sheets

III. Suggested Teaching Calendar

IV. Demonstration of lessons/labs

- A. Scientific Method (06.00)
  - 1. LS: 06.00.PL or LS: 06.00.IL
    - a. Teacher Instructions
    - b. Student Handout

- B. Examining Plant Structures and Functions (06.01)
  - 1. LS: 06.01.PL or LS: 06.01.IL
    - a. Teacher Instructions
    - b. Student Handout

- C. Determining the Importance of Photosynthesis and Respiration (06.02)
  - 1. LS: 06.02.PL or LS: 06.02.IL
    - a. Teacher Instructions
    - b. Student Handout

- D. Propagating Plants Sexually (06.03)
  - 1. LS: 06.03.A.PL or LS: 06.03.A.IL
  - 2. LS: 06.03.B.PL or LS: 06.03.B.IL
    - a. Teacher Instructions
    - b. Student Handout

Section III: Conclusion (Same for all three versions)

I. Contact Information

II. Conclusion and Thank you

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BIOGRAPHICAL SKETCH

Brian Eugene Myers was born July 22, 1974, in Pittsfield, Illinois. Mr. Myers was raised on his family's farm in rural Pike County, Illinois. He graduated from Pittsfield High School in 1992. While attending high school, Mr. Myers was very active in 4-H and FFA.

Mr. Myers received his Bachelor of Science (c*um laude*) degree in general agriculture with a specialization in agriculture education from Southern Illinois University in Carbondale in 1996. As part of his degree program, he completed his student teaching at Mt. Vernon Township High School in Mt. Vernon, Illinois, under the supervision of Mr. John Kabat.

Upon graduating, Mr. Myers accepted a dual graduate assistantship from both the Agricultural Education and Mechanization and Plant and Soil Science Departments at Southern Illinois University at Carbondale. As part of his duties, Mr. Myers taught courses in agricultural education and the Introduction to Crop Science laboratory sections. Additionally, Mr. Myers was the advisor for the SIUC Collegiate FFA and as such worked closely with teachers in southern Illinois in planning several FFA events. Mr. Myers received his Master of Science degree in agricultural education and mechanization specializing in agricultural education in 1997.

Following the completion of his M.S. degree, Mr. Myers accepted an agricultural education teaching position at Unity High School in Mendon, Illinois. While at Unity High School, Mr. Myers taught students in grades eight through twelve in many areas of agricultural education as well as Tech Prep courses. In addition to his duties as an agricultural educator, Mr. Myers was an active member of the community, serving on many boards and committees such as the Adams/Brown Cooperative Extension Administrative Board.

Mr. Myers was a member of the Illinois Association of Vocational Agriculture Teachers, the National Association of Agricultural Educators, the National Science Teachers Association, Phi Delta Kappa, and numerous other educational organizations. His efforts as an agricultural education teacher and FFA advisor have been recognized by numerous organizations, including being named Illinois' 1st runner up of the NAAE Outstanding Young Member award.

Mr. Myers also worked as an educational consultant with the Center for Agricultural and Environmental Research and Training. Mr. Myers has conducted numerous professional development workshops for agricultural educators across the country in the areas of agriscience curriculum development and implementation. He has also authored major portions of the agricultural education curriculum in several states.

In 2001, Mr. Myers accepted a graduate teaching and research assistantship with the Agricultural Education and Communication Department at the University of Florida and began work on a Ph.D. in agricultural education. Mr. Myers taught or assisted with numerous undergraduate and graduate courses in department as well as supervised student teachers. Additionally, he conducted numerous research studies in the area of agricultural education.

Mr. Myers was married to Margaret Jahnke in July of 1997. They have a son, Timothy, born in July of 2000.