THE INFLUENCE OF CONTEXTUAL TEACHING WITH THE PROBLEM SOLVING METHOD ON STUDENTS' KNOWLEDGE AND ATTITUDES TOWARD HORTICULTURE, SCIENCE, AND SCHOOL

A Dissertation

by

CARRIE LYNN WHITCHER

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2005

Major Subject: Horticulture

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Approved by:

Chair of Committee,	Jayne M. Zajicek
Committee Members,	Gary Briers
	J. Tom Cothren
	R. Daniel Lineberger
Head of Department,	Tim Davis

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ABSTRACT

The Influence of Contextual Teaching with the Problem Solving Method on Students' Knowledge and Attitudes Toward Horticulture, Science, and School.

(August 2005)

Carrie Lynn Whitcher, B.S. California State University, Chico;

M.S., California State University, Chico

Chair of Advisory Committee: Dr. Jayne M. Zajicek

Adolescence is marked with many changes in the development of higher order thinking skills. As students enter high school they are expected to utilize these skills to solve problems, become abstract thinkers, and contribute to society.

The goal of this study was to assess horticultural science knowledge achievement and attitude toward horticulture, science, and school in high school agriculture students. There were approximately 240 high school students in the sample including both experimental and control groups from California and Washington. Students in the experimental group participated in an educational program called "Hands-On Hortscience" which emphasized problem solving in investigation and experimentation activities with greenhouse plants, soilless media, and fertilizers. Students in the control group were taught by the subject matter method. The activities included in the Hands-On Hortscience curriculum were created to reinforce teaching the scientific method through the context of horticulture. The objectives included evaluating whether the students participating in the Hands-On Hortscience experimental group benefited in the areas of science literacy, data acquisition and analysis, and attitude toward horticulture, science, and school.

Pre-tests were administered in both the experimental and control groups prior to the research activities and post-tests were administered after completion. The survey questionnaire included a biographical section and attitude survey.

Significant increases in hortscience achievement were found from pre-test to post-test in both control and experimental study groups. The experimental treatment group had statistically higher achievement scores than the control group in the two areas tested: scientific method ($p=0.0016$) and horticulture plant nutrition ($p=0.0004$).

In addition, the students participating in the Hands-On Hortscience activities had more positive attitudes toward horticulture, science, and school ($p=0.0033$). Students who were more actively involved in hands-on projects had higher attitude scores compared to students who were taught traditional methods alone.

In demographic comparisons, females had more positive attitudes toward horticulture science than males; and students from varying ethnic backgrounds had statistically different achievement ($p=0.0001$). Ethnicity was determined with few students in each background, 8 in one ethnicity and 10 students in another. Youth organization membership such as FFA or 4-H had no significant bearing on achievement or attitude.

DEDICATION

To Claude

My best friend, hiking companion, fiance, and partner in life.

Thank you for believing in me, supporting me, and loving me throughout this entire endeavor.

I never would have completed this journey without you by my side and I dedicate this research and dissertation to you.

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Gig ‘em Aggies!

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CHAPTER I

INTRODUCTION

Experiential learning has been shown to promote increased knowledge in skilled and technical areas (Boone, 1988a; Chuatong, 1986; Collins, 1991; Crunkilton and Krebs, 1982; Dewey, 1916; Fleming and Malone, 1983; Freedman, 1997; Gunsch, 1972; Lancelot, 1944; Newcomb et al., 1993; Osborne and Hamzah, 1989; Phipps and Osborne, 1988; Roegge and Russell, 1990; Rothenberger and Stewart, 1995; Rousseau, 1979; Stohr-Hunt, 1996; Thompson and Balschweid, 2000; Thompson and Tom, 1957). Whether it is called hands-on learning, problem solving, contextual teaching and learning, inquiry centered learning, authentic learning or constructivism, students benefit from learning because they learn to apply knowledge, the learning environment fosters invention and creativity, they see the implications of the knowledge, and they see the knowledge is organized for appropriate used in context (Collins, 1991). This in turn stimulates interest and passion for the subject area, sometimes referred to as a "felt need" (Dewey, 1916).

High quality achievement occurs in the classroom when students have a felt need or interest in the subject matter (Dewey, 1916; Lancelot, 1944; Rousseau, 1979). These respected proponents of experiential learning all believed that if students thought that what they were learning was interesting, they would never question why it would be necessary to learn it. It would never occur to a student why they had to

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This dissertation follows the recommended style and format of HortTechnology.

learn something because they wanted to. Linking need to interest captures and motivates students and improves attitudes toward education.

When students have interest in their education, positive attitudes usually follow. Activities that make science vivid, meaningful and fun for students are those with hands-on application (Le Buffe, 1994; Wasserstein, 1995). Wasserstein (1995) found that middle school students identified their most memorable school work as being hands-on science activities over any other topic or class activity. Hands-on or experiential learning studies have shown that students in an experiential group had considerably more positive attitudes toward science than their counterparts in a traditional lecture/subject matter science class (Flowers, 1986; Kyle et al., 1988; Roegge and Russell, 1990). In addition, positive attitudes of students toward science have been shown to lead students to enroll in additional science courses (Simpson and Oliver, 1990; Tanner, 1980).

High school students' attention is consumed by electronic media, the World Wide Web (WWW), sports, and video games. The information revolution has occurred with the presence of the WWW and students know they can obtain any information whenever they need it. Today's learning environments have reached an apparent conflict between problem solving and information dissemination, between abstract and concrete learning, and between concepts and applications (Osborne, 1999). Students see little connection between their education and their daily lives and do not see why education, particularly science education, is important (Connors and Elliot, 1995). Some students ask "If I have a problem on an assignment, why not just look the answer up on the

Internet?" They fail to realize the importance of solving problems to cognitive development and that not all problems are easily solved with the click of a mouse.

Solving problems has been the link between experiential learning strategies and increasing science process skills (observing, communicating, comparing, ordering, relating, and inferring), (Edwards and Briers, 2000; Ostlund, 1992; Roth and Roychoudhury, 1993) and is crucial to cognitive construction and future application. These are skills necessary for higher order thinking skills (Bloom, 1956; Boone, 1990).

The major goal of this research project was to bring together common teaching methods, educational topics in experimentation, investigation, and the scientific method, and knowledge of horticulture nutrition in order to study the effects of contextual, problem solving teaching methods on high school agriculture students.

Objectives

To accomplish the above stated goal, Hands-On Hortscience (Whitcher, 2004), a program built around the problem solving (PS) and contextual teaching and learning (CTL) methods was incorporated into the curricula of several high school agriculture programs. The main objectives for this research were to: 1) develop a Hands-On Hortscience horticulture science workbook for high school agriculture teachers to integrate into the classroom agriscience curriculum, 2) evaluate the Hands-On Hortscience Program which included PS/CTL increased students' achievement test scores in both horticulture and the scientific method, and 3) evaluate whether students participating in the Hands-On Hortscience Program developed positive horticulture science attitudes.

Research Hypotheses

Based on the purpose and objectives of this study, the following null hypotheses were tested:

H_{01}: Participation in the Hands-On Hortscience Program does not increase participants' knowledge of the scientific method, investigation, and experimentation.

H_{02}: Participation in the Hands-On Hortscience Program does not increase participants' knowledge of horticulture plant nutrition.

H_{03}: Participation in the Hands-On Hortscience Program does not increase participants' attitude toward science and school.

H_{04}: Positive effects due to participation in the Hands-On Hortscience Program do not vary due to differences in demographic variables of the participants.

Definition of Terms

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

Achievement: Level of knowledge gained through the school environment, as measured by change in scores on school assignments.

Attitude toward school: one's opinion or regard of the utility of school and of school-related matters.

Cognition: Refers to thinking processes, and formal content knowledge learned in school.

Problem solving (PS) approach: a student-centered instructional approach recommended for teaching vocational agriculture. The steps during the lesson are previous lesson review, interest approach, development of student objectives, identification of problems and concerns of students, discussion and development of possible solutions to problems, conclusions, evaluation, and application (Flowers, 1986).

Contextual teaching and learning (CTL) approach: a student-centered method of teaching where the lesson is set in an in-school or out-of school setting in order to solve simulated or real world problems. This strategy emphasizes higher-level thinking skills and knowledge transfer across academic disciplines and collecting, analyzing and synthesizing information and data from multiple sources and viewpoints (Smith, 2000).

Subject matter approach: a teacher-centered method of teaching where the lesson is focused on covering the subject matter during a specified time period. The steps during the lesson are previous lesson review, introduction, presentation of subject matter by the teacher, review, and evaluation (Flowers, 1986).

Basic Assumptions

This research was conducted with high school agriculture students who participated in the Hands-On Hortscience, A Problem to Solve: The Scientific Method program. It was assumed that all students who participated in the experimental group participated in problem solving learning methods using horticulture, specifically plant nutrition as the context.

It was assumed that all students in the experimental group participated in the plant growth investigation and experimentation research exercises.

It was assumed that students in the experimental group were provided with the greenhouse growing materials and supplies (plants, fertilizer, soilless media, rulers, pots, and labels).

It was assumed that the assessment tool was presented and administered to the students impartially within an ample time frame.

It was assumed that the assessment tool was administered fairly and that each student answered the test independently (with the exception of English Language Learners or visually impaired students, who had assistance from interpreters or staff).

It was assumed that the pre-tests were administered before the treatment began and that the post-tests were administered after the treatment ended.

It was assumed that the students answered the assessment tool truthfully and to the best of their ability.

Limitations

This study was limited to the schools and students who voluntarily agreed to participate in the study and, therefore, lacked randomization. This study was also limited to certain grade levels based on the curriculum. For this reason, the study did not include all students in the participating high schools. Because of the voluntary nature of participation, the students tested may have varied in their responses due to different backgrounds, histories, and experiences. Individual teaching methods and treatment administration of the curriculum may have been limited in this study. Individual agriculture programs may have had different greenhouse growing facilities, supplies, and equipment.

Delimitations

The population of this study was delimited to those schools and students who voluntarily agreed to participate in the research study during the fall of 2004 and spring 2005 semesters.

CHAPTER II

REVIEW OF THE LITERATURE

The literature reviewed in this chapter looks at the subject of student interest in school through horticulture science education. The contextual teaching and learning (CTL) and the problem solving teaching (PS) sections are similar methods of classroom education delivery, the former in science education and the latter in agricultural education. The literature is grouped into the following categories:

1. Science in Agricultural Education
2. Contextual Teaching and Learning
3. Problem Solving (Inquiry Centered) Teaching
4. Summary of Literature

Science in Agricultural Education

History

The Hatch Act of 1887 established agricultural experiment stations in US universities, with most having an associated agriculture school that led to both practical and scientific application of agricultural developments (Hillison, 1996). Teaching was conducted by scientists who focused on scientific principles that were underlying factors in agricultural production (not the daily production practices but rather the science behind the methods). The term agriculture science was born at this time (Hillison, 1996), and science research was committed to assisting farmers with the specific knowledge behind their agricultural practices.

The passage of the Smith-Hughes Act in 1917 made agricultural education in secondary schools a part of vocational education, focusing more on skills training than on scientific research. This training became the workforce of American farm laborers which led to the United States becoming the leader in world food production (Shelley-Tolbert et al., 2000). In the beginning of the 20^{th} century, the Industrial Revolution was expanding and the need for skilled workers was increasing. Through support by National Society for the Promotion of Industrial Education and Association of Agricultural Colleges and Experimental Stations, federal aid was secured for vocational education in secondary schools (Finch and Crunkilton, 1999). Philosopher John Dewey believed that the industrial education movement of the day had some positive potential but felt it should prepare the way for a more humane technological society, a place where "science, technology, and democracy would complement each other" (Wirth, 1991). Charles Prosser strongly supported the idea of social efficiency, which contends that schools should be reformed to meet the needs of a technocratic society. Prosser firmly imbedded the idea of dualism in education, setting the stage for vocational education being separate and distinct from academic education (Finch and Crunkilton, 1999). Unfortunately for Dewey, Prosser's philosophy prevailed and was included in the Smith-Hughes Act. Among other things, this landmark legislation set the stage for vocational education being separate and distinct from academic education (Finch and Crunkilton, 1999), most notably, science education.

During the 1960s, the world began shifting from distinct country economies to a global economy, resulting in a shift from regional and national bases to an international venue. A technological revolution was occurring with the entrance of computer technology into the workplace. With computers came increased needs for improved mathematics and science knowledge of employees (Finch and Crunkilton, 1999). The United States was lacking workers with these added academic skills, coupled with vocational skills, and this called for immediate attention of the federal government. The Carl D. Perkins Vocational and Applied Technology Education Act of 1990 (Perkins II) was founded to offer states financial incentives to create and operate educational programs that have a goal of producing a more competitive worker, a worker who was cooperative, a team player, and better able to integrate academic knowledge with vocational skills (Binkley and Tulloch, 1981; Finch and Crunkilton, 1999). Also included in Perkins II were provisions for using Tech Prep to link high school and post-high school curricula in creative and beneficial ways. Tech Prep was originally conceived by Dale Parnell, Gene Bottoms, Leno Pendrotti, and Dan Hull as a 2 + 2 articulation program (secondary/postsecondary) for general-track high school students, those who had no plans and little opportunity for a baccalaureate degree (Hull, 1995). The idea was students would take vocational courses in high school and articulate them with those offered at junior colleges, eliminating the need to repeat basic courses in vocational departments. Reports of renewed student interest, achievement, and retention in high school emerged from all over the United States, from the Carolinas, Rhode Island, and Virginia to Oklahoma, Texas, Florida, California, and Oregon. Perkins II increased Tech Prep's federal funding from sixty million to over 100 hundred million dollars and by 1990 over 1000 new Tech Prep consortia were launched (Hull, 1995). From 1984 to 1993, national consortia developed, tested and successfully implemented applied-academics curriculum materials in physics, mathematics, biology/chemistry, and communications (Bottoms and Presson, 1989). The interest in Tech Prep and its successes has many math and science educators recognizing that the applied or contextual teaching approach is a more effective teaching strategy for high school students (Hull, 1995). To date, nearly 47% of the high schools in the United States (almost 7,400 schools) offer Tech Prep programs (ed.gov, 2005) with thousands of students transferring to two-year and four-year colleges and universities to obtain program certificates and college degrees.

Challenges in Science Education

Science achievement scores for high school students is declining (National Center for Education Statistics, 2005b; O'Sullivan et al., 2003; U.S. Department of Education, 2000). Between 1996 and 2005:

- The percentage of 12th graders at or above basic science level declined.
- There was no statistically significant difference observed in the average science scores of fourth- or eighth-grade students. The average score of students in grade 12, however, declined from 150 in 1996 to 147 in 2000.
- Average scores decreased for eighth-grade American Indian students and for 12th grade White students.
- Science scores of fourth and eighth grade students has increased slightly over the last few years to sixth and ninth, respectively, out of 45 countries surveyed in 2003 by the Trends in International Mathematics and Science Study (TIMSS) (Snell, 2005).

These science test results have increased the demand for improved science education for American students, which translates into schools being asked to teach more content within science courses and demand greater numbers of courses taken prior to graduation. This demand has resulted in students taking more science classes but not responding to the workload.

The American Association for the Advancement of Science (AAAS), publisher of the largest paid, peer-reviewed general science journal in the world (*Science*), sought to increase science awareness and advance literacy in mathematics, science, and technology by developing Project 2061 in 1985. A fundamental premise of Project 2061's *Science for All Americans* 1989 report is that the schools do not need to be asked to teach more and more content, but rather to focus on what is essential to scientific literacy (AAAS Benchmarks) and to teach it more effectively (American Association for the Advancement of Science, 1993). This suggests new methods of teaching science are needed (Connors and Elliot, 1995; Crunkilton, 1984; Le Buffe, 1994; Osborne, 1999; Roegge and Russell, 1990; Wasserstein, 1995).

Secondary schools in today's society are faced with the challenge of increasing curricular rigor to strengthen the knowledge base of high school graduates, while at the same time increasing the proportion of all students who successfully complete a high school program. Monitoring high school dropout and completion rates provides one measure of progress toward meeting these goals (Kaufman et al., 2000). Teachers can contribute to their students' completion of high school by providing experiences for them that are meaningful and relate to the student's personal education, making school more attractive. The inclusion of problem-solving teaching has been a key element and central approach in agriculture education, making learning fun and interesting (Chuatong, 1986; Connors and Elliot, 1995; Crawford, 2001; Crunkilton, 1984; Darling-Hammond and Falk, 1997; Dewey, 1916). Students are more aware of the connection between scientific principles and agriculture and are better prepared to apply science concepts when they see a connection or a felt need with their own lives (Campbell, 1994; Crowell et al., 1998; Knobloch, 2003; Parr and Edwards, 2004; Thompson and Balschweid, 2000).

With the federal No Child Left Behind (NCLB) Act in 2002, science and mathematics educators have been challenged to improve science education by addressing teacher quality standards within each state of the United States. The charge of NCLB is to require each state to become accountable for bridging the achievement gap of its students. This will be done by incorporating more resources into professional development, providing $2.8 million dollars in federal grants for improving teacher quality, implementing education technology and innovative educational programs (National Science Teachers Association, 2005; U.S. Department of Education, 2002). Questions arise about NCLB, what makes a quality teacher or quality educational program? What teaching methods encourage some students to succeed in science yet not in others? Is student centered teaching methods the key to improving science education?

Limited evidence exists to support the concept that science teachers look for ways to integrate more hands-on applied science concepts into the science curricula (Balschweid, 2002; Boone and Newcomb, 1990) and when teachers are challenged in using a new teaching method they may fall back into lecturing (Boone and Newcomb, 1990; Crawford, 2001; Flowers, 1986). The problem solving approach has been used in agriculture education but has waned in the past 10 years (Osborne, 1999; Osborne and Hamzah, 1989).

Student Attendance in School

Fewer students are enrolling in elective courses due to increased graduation credit demand, and the overall dropout rate for high school students is 5%, calculated using the October 1999 Child Protective Service (CPS) data measure the proportion of students who dropped out between October 1998 and October 1999. These dropouts are 15- through 24-year-olds who were enrolled in high school in October 1998, but had not completed high school and were not enrolled in grades 10–12 a year later.

Because high school completion has become a requirement for accessing additional education, training, or the labor force, the economic consequences of leaving high school without a diploma are severe. On average, dropouts are more likely to be unemployed than high school graduates and to earn less money when they eventually secure work (U.S. Department of Education, 1999). High school dropouts are also more likely to receive public assistance than high school graduates who do not go on to college (U.S. Department of Education, 1998). This increased reliance on public assistance is likely due, at least in part, to the fact that young women who drop out of school are more likely to have children at younger ages and more likely to be single parents than high school graduates (McMillen and Kaufman, 1994). The individual stresses and frustrations associated with dropping out have social implications as well:

dropouts make up a disproportionate percentage of the nation's prison and death row inmates (U.S. Department of Justice, 1991). Estimates indicate that one-quarter of federal and one-half of state prison inmates are high school dropouts.

Benefits of Agriscience in Education

Agriscience teachers have been advised to integrate science concepts into their curricula in an attempt to make science relevant to their students (Balschweid, 2002; Balschweid and Thompson, 2000; Chiasson and Burnett, 2001; Connors and Elliot, 1995; Dormody, 1993; Knobloch, 2003; Parr and Edwards, 2004; Roegge and Russell, 1990). Agriscience students have earned higher science test scores than non-agriscience students on the life science portion of the Graduate Exit Examination (GEE) in Louisiana (Chiasson and Burnett, 2001). In this case, the non-agriscience students achieved higher scores in the physical sciences and chemistry. Results show unanimous support for more science-based instruction in agriculture but little agreement on how much, or how best, to integrate (Shelley-Tolbert et al., 2000).

Each student’s learning occurs through one of Gardner’s eight multiple intelligences (linguistics, music, logical/mathematical, spatial, bodily/kinesthetic, interpersonal, intrapersonal, and naturalistic modes) (Gardner, 1999). The type of intelligence a student possesses will determine how he/she solves problems and ultimately the success he/she has in class. In many agriculture courses information is presented in several different formats providing distinct opportunities for students who learn through the multiple intelligences avenues for academic success. Work done by

Flowers (1986) showed that students had higher rates of retention in knowledge from agriculture courses after being taught with the problem solving method.

Contextual Teaching and Learning (CTL)

Overview

Contextual teaching and learning is both a philosophy of education and a continuum of pedagogical strategies (Center for Occupational Research and Development, 2000b; Smith, 2000). As a philosophy of education it assumes that an educator's role is to help students find meaning in their education by making connections between what they are learning in the classroom and ways in which that knowledge can be applied in the outside world. It is intended to help students understand why what they are learning is important. Contextual teaching and learning has been defined as teaching that enables learning where pupils employ their academic understanding and abilities in a variety of out-of-school contexts to solve complex, real world problems, both alone and in various group lectures (Shelley-Tolbert et al., 2000). Teachers have long used school farms and greenhouses to infuse hands-on activities to bring students closer to instruction (Arnold et al., 2001; Lohr, 1992; Rothenberger and Stewart, 1995; Skelly and Zajicek, 1998). Contextual teaching and learning instructional strategies incorporate techniques that help students become more actively engaged as learners and reflective about their experiences. It emphasizes higher-level thinking, knowledge transfer across academic disciplines, and collecting, analyzing and synthesizing information and data from multiple sources and viewpoints (Smith, 2000).

Contextual learning is not a new idea and is rooted in the educational philosophy of many since the time of William James (as cited in Parnell, 1995) and John Dewey (1916) to the present. In contextual teaching, it is the major task of the teacher to broaden students' perceptions so that meaning becomes visible and the purpose of learning immediately understandable. This is fundamental if students are to be able to connect knowing with doing (Parnell, 2001). Vocational education is a method of connecting with the student in a personal, meaningful way.

Contextual learning is not just rooted in philosophy and our nation's legislative history but is also biologically compatible (Crawford, 2001). Recent research on understanding how the brain functions has shed light on the importance of making connections in what we learn (Caine and Caine, 1991; Jensen, 1995). In the 1970s a popular term used for CTL was experiential learning. In the 1970s and 1980s it was also called applied learning. The Secretary's Commission on Achieving Necessary Skills (U.S. Department of Labor, 1991) concluded the most effective way of learning skills students will be expected to apply is "in context", placing learning objectives within a real environment rather than insisting that students first learn in the abstract.

Six elements were identified as important for the application of CTL for lifelong learning (Owens et al., 1999). These are:

1. meaningful learning;
2. application of knowledge;
3. higher-order thinking skills;
4. standards-related curriculum;
5. cultural-responsiveness, and
6. authentic assessment.

Life roles, or human commonality roles, are addressed in CTL for lifelong learners (Parnell, 1995). These include those roles in life that all humans undertake as a result of becoming a member of society that they will perform throughout their lives: 1. lifelong learner, 2. citizen, 3. consumer, 4. producer, 5. individual, 6. family member, and 7. aesthetic/leisure participant. Learning through real-world contexts adds to the knowledge base of students, providing for a fresher appeal to students' inquisitive minds and stimulation of interests in their surroundings. This is the basis of educating for freedom, a freedom to enter with others into social and civic association (Finkel and Arney, 1995)

Use of CTL in Science Education

Science education has seen a pedagogical shift from a teacher-centered to a student-centered instructional paradigm (Von Secker and Lissitz, 1999). Inquiry-based, contextual learning has been praised for requiring the student to do more than just report on a topic. In a study evaluating the effects of implementation of learner-centered teaching methods on tenth-grade science achievement, Von Secker and Lissitz (1999) found that students' mean science achievement increased for every increase in the amount of emphasis placed on laboratory inquiry. In a community college biology course, students who were instructed in a contextual, inquiry-based approach showed greater improvement in reasoning ability than students taught in a teacher-directed approach (Johnson and Lawson, 1998).

New instructional materials have targeted CTL in the life sciences, particularly biology (Center for Occupational Research and Development, 1998; Center for

Occupational Research and Development, 2000a; Center for Occupational Research and Development, 2000b). These materials provide lessons, laboratory exercises, and creative ideas for teachers to use with their students to address science standards through hands-on projects and real-world scenarios, addressing "Why do I have to learn this?"

Uses of CTL in Other Populations

The subject rated "interesting" by the fewest numbers of students at both junior and senior high levels is English. Students choose as their favorite classes ones where they routinely collaborate with other students and the teacher, where they have some degree of ownership of the educational product, and where they can be active - where whole-group listening and busy work are minor components of the educational process (Atwell, 1987). Use of a "workshop" format to stimulate interest in students with varying abilities has been used in English and Social Studies classes with success in junior and senior high school (Atwell, 1987; Seabrook, 1991) and college philosophy and English university classes (Finkel, 2000). University educational courses have also used a CTL method called "action research" in their classrooms. Student teachers or graduate students in education look at a classroom situation, practice or problem and work to solve it by addressing the issue, taking notes on improvements, student-centered learning, and enriching the knowledge base for learning (Hall et al., 1997).

Vocational training for populations outside high school or the university setting has seen significant results with contextual learning within the discipline of horticulture. Use of the Green Brigade™ program in Texas, a horticulture program for juvenile offenders during incarceration, increased horticulture knowledge and environment attitudes upon completion of the program while earning wages (Dawson, 1998; Finch, 1995; Migura et al., 1997; Migura and Zajicek, 1997). Pride, self-esteem, and seeing personal growth was achieved through a job well done are the same accomplishments for some individuals as earning class grades for others.

Problem Solving (PS or Inquiry-Centered) Teaching

Overview

Another way to look at practical education is learning through inquiry and problem solving. Problem solving teaching methods have been touted in agricultural education as beneficial to all students (Boone, 1990; Connors and Elliot, 1995; Crunkilton, 1984; Crunkilton and Krebs, 1982; Dormody, 1992; Dyer and Osborne, 1996b; Flowers, 1986; Flowers and Osborne, 1988; Knobloch, 2003; Krebs, 1982; Lancelot, 1944; Newcomb et al., 1993; Osborne and Hamzah, 1989; Parr and Edwards, 2004; Pate et al., 2004; Roegge and Russell, 1990; Rothenberger and Stewart, 1995; Thompson and Balschweid, 2000; Thompson and Tom, 1957).

Problem solving gives teachers the option of cooperative learning, often leaving out “Telling”, teacher-directed lectures, leaving students with the personal power to direct their own learning (Finkel, 2000). When teachers do plan a lecture, it is often poorly organized and boring to students. Sometimes there is poor flow between parts of the lecture and it is not uncommon to find that in planning a lecture teachers fail to plan for and develop clear conclusions (Newcomb et al., 1993; Stolovitch and Keeps, 2002). The majority of what people learn has been acquired by doing some activity, in a procedural way. Procedural knowledge comes from learning through hands-on activities. Teachers know about the subject they are going to lecture because they have read it, studied it, and presented it in the past to other classes. The problem with lecturing is that it is a means of transmitting information in a declarative manner (name, explain, and/or talk about). Declarative knowledge comes from the ability to name, explain, or describe different subjects, but many students learn in the form of procedural knowledge (Stolovitch and Keeps, 2002) by experimentation, seeing the results, and actively participating in an activity. Processing both types of knowledge is done very differently by the brain and is the key point behind "easier said than done". By transforming a teacher's declarative knowledge (such as how to transplant seedlings into larger pots) into procedural instructions, students can understand it and carry it out (what to do first, then second, and so on). Learning from declarative methods can be a slow process unless similar procedural knowledge is already known by the students (Stolovitch and Keeps, 2002). Connection of previous knowledge to current instruction is crucial for continued learning by students.

Another difficulty with lecturing as a primary teaching technique is that lecturers often lack animation, and fail to use clear illustrations or sufficient visual media (Newcomb et al., 1993). Open-ended seminar, in-class study groups, conceptual workshops, backwards design lessons, hands-on laboratory activities, and formal class presentations are all activities that are useful in PS (Finkel, 2000; Hall et al., 1997; Stolovitch and Keeps, 2002; Wiggins and McTighe, 1998). The focus of PS is creating circumstances and an environment that may foster an experience for students, an experience that will lead to interest and learning (Rousseau, 1979).

In the old-fashioned classroom, the teacher's primary role was to convey facts and procedures. The students' roles were to memorize the facts and practice the procedures by working skill drill exercises and, sometimes, word problems. Students who could recall and repeat the appropriate facts and procedures scored well on the end-of-unit or end-of-semester test. By contrast, in a contextual or inquiry-based classroom, the teacher's role is expanded to include creating a variety of learning experiences with a focus on understanding rather than memorization. Teachers who incorporate problem solving use the strategies discussed above (relating, experiencing, applying, and cooperating) and assign a wide variety of tasks to facilitate learning for understanding. In addition to skill drill and word problems, they assign experiential, hands-on activities and realistic problems through which students gain initial understanding and deepen their understanding of concepts. Here the use of the WWW as a research tool to be discovered and used by students is an important part of the inquiry process. Access and utilization of current industry and educational websites, computational calculators, and journal and industry magazine articles are vital to bringing additional resources to classrooms that cannot afford complete classroom reference textbooks, field trip funding, or research materials.

Problem Solving in Agriculture Education

Integration of agriculture gardening projects in elementary education curricula which utilizes problem solving skills has been shown to increase agriculture knowledge and improve attitudes toward school (DeMarco et al., 1999; Klemmer, 2002; Meunier et al., 2002; Robinson, 2001; Waliczek, 1997). High school students have access to agriculture education and FFA (Campbell, 1994; Chiasson and Burnett, 2001; Harwell, 1999; Marler and Discekici, 1995) providing Supervised Agricultural Experience (SAE) programs to students in agribusiness, agricultural communications, agriculture mechanics, horticulture, animal science, forestry and natural resources, and crop production. Students' SAE are hands-on projects of four types: exploratory, research/experimentation and analysis, ownership/entrepreneurship or placement which provide vocational training in any of the above mentioned areas (Stagg, 2005). Supervised Agricultural Experiences were the product of Rufus W. Stimson, a leader in shaping agricultural education at the high school level (Knobloch, 2003). Stimson was the "father" of the hands-on project method of teaching, which are now called SAE projects (Moore, 1988). The most important part of a student's SAE is that he or she selects it; that is, it is their own personal project they develop throughout their high school career while enrolled in agriculture courses. Some students take on additional projects, some have very few or one large project. The hands-on, vocational training through the SAE gives students skills they cannot get from books or lecture. "Neither skill nor business ability can be learned from books alone, nor merely from observation of the work and management of others. Both require active participation, during the learning period, in productive farming operations of real economic or commercial importance" (Stimson, 1919). Stimson predicted the effectiveness of agriscience fair projects because the "project study…will probably prove to be one of the most effective means of accumulating first-hand data for the successful study of science…" (Stimson, 1919).

Problem solving curriculum allows teachers to utilize the cooperative group concept, allowing students to develop his or her ideas and answer problems but have the opportunity to share these ideas with colleagues in a peer-review fashion. A unique problem solving technique was developed for use between pairs of students, the thinking aloud pair problem solving (TAPPS) strategy (Pate et al., 2004). TAPPS requires two students to work together to solve a problem where one student troubleshoots the problem while his/her partner listens to him/her explain why he or she is doing a certain task and questions why certain steps or strategies were taken at that time to solve the problem. The questioning partner, called the listener, hears what the troubleshooting partner has to say, and probes further, especially during periods where the troubleshooting student seems to be stuck or does something incorrectly. The listener does not offer advice or give assistance, just probes and questions, getting the troubleshooter to think about why he or she did a specific thing to the project in question.

In addition to student peers, teachers also take on the role as colleague, adding a new dimension to learning that the vast majority of students never see. Students may develop class-oriented games and activities (Smith and Rogers, 1998) or case-studies (Allen et al., 1995; Kuehny and McMahon, 1998). The overall difference between CTL and PS is that CTL may utilize traditional teaching strategies (lectures, labs, homework) where PS utilizes group-based or cooperative learning strategies (emphasis on writing, group analysis of problems through laboratory development and analysis, and understanding written lectures) to convert the products of knowledge into the processes that lead to them (Finkel, 2000; Wiggins and McTighe, 1998). Problem solving and CTL both add meaningful, personal experiences for students they themselves develop and process. Instead of listening to a lecture, the students seek out the tenets of the lecture through carefully designed experiences and activities. Teachers also need to plan ways to gain the interest of students and create, on the part of students, such a feeling of “need to know” that the students will be willing to invest time and energy in coming up with answers they need in order to remove the felt need and actually solve the problem being studied (Newcomb et al., 1993). Both philosophies do not lessen any work by the classroom teacher and may require a more organized personality, a teacher more interested in helping students achieve a product of experience other than a notebook full of random assignments (Harwell and Blank, 2001).

Flowers (1986) discovered no significant difference between students taught by the problem solving approach and students taught by the subject matter approach on student achievement, and no significant difference between both methods on attitudes toward the teaching method in introductory vocational education courses. He determined a significant difference in student achievement retention scores in favor of the problem solving treatment group, in that they had greater knowledge retention. Are high school freshmen capable of incorporating and utilizing higher-level thinking strategies and problem solving methods? Both problem solving and teacher-centered learning were compared by Boone and Newcomb (1990) in high school vocational agriculture courses.

Problem solving teaching was found to be more successful when taught first in a two-unit sequence.

Problem Solving Use in Agriculture Education

The use of quick, short student projects have been shown to have an advantage over longer, quarter-length projects (Mabie and Baker, 1996) in elementary students. When comparing both project groups to traditional learning methods that were completely teacher-centered, both short and long project groups had greater success in student learning. This agrees with the results seen by Finkel (2000) in a conceptual workshop assignment.

The use of problem solving in PS or CTL methods can add to student interest and learning (Chuatong, 1986; Crunkilton and Krebs, 1982; Flowers, 1986; Newcomb et al., 1993; Rousseau, 1979). Reflective thinking is the basis of a problem solving approach to teaching and teachers can develop a 6-step process to design problem solving activities (Crunkilton and Krebs, 1982):

1. Interest approach;
2. Group objectives;
3. Questions to be answered;
4. Problem solution;
5. Testing solutions through application;
6. Evaluation of solutions.

The teacher begins a unit of study with the interest approach that is designed to get the students' attention and proceeds into a discussion of why this information or unit is important. Students formulate reasons why this topic relates to their SAE program and what they will need to know to design it and maintain it effectively. That is, they must develop a set of questions they will need to answer about this topic. By developing a list of reasons for studying the unit and deriving a list of questions to answer, students will have defined the problem (Newcomb et al., 1993). The SAE is a part of every student's course of study in a high school agriculture class. Regular coursework and participation in FFA (formerly known as Future Farmers of America) activities are also mandated in secondary agriculture curriculum. It is the overlapping of instruction, hands-on laboratory, and FFA career development events and activities that reinforce lessons, ideas, and skills training that have been shown to lead to student success (Flowers, 1986; Townsend and Carter, 1983).

The learning process can be directly related to the problem solving approach (Newcomb et al., 1993) in the following steps:

Learning Process	**Problem Solving Approach to Teaching**
1. Experiencing a provocative situation;	1. Interest approach;
2. Defining the problem;	2. Group objectives;
3. Seeking the data and information;	3. Questions to be answered;
4. Formulating possible solutions;	4. Problem solution;
5. Testing proposed solutions;	5. Testing solutions through application;
6. Evaluating the results.	6. Evaluation of solution.

Connecting problem solving with science education in agriculture is an element in student achievement and success (Boone, 1990; Crunkilton and Krebs, 1982; Newcomb et al., 1993; Phipps and Osborne, 1988).

There are limited studies of the use of problem solving exercises in agriculture classes (Balschweid and Thompson, 2002; Boone, 1988a; Boone, 1990; Chuatong, 1986; Osborne and Hamzah, 1989; Roegge and Russell, 1990). As students enter their final two years in secondary education, they have options of enrolling in advanced agriculture courses and all of these courses may qualify for science graduation credits. It would be beneficial for agriculture teachers to know what is involved with experiential learning through PS and how much more time would be involved planning and organizing CTL/PS lessons and conceptual workshops.

CHAPTER III

METHODOLOGY

The purpose of this study was to assess the effects of teaching method on investigation and experimentation achievements of high school students enrolled in agriculture courses and evaluate the attitudes of students upon completion of the teaching unit. Included in this section are 1) the population demographics of participating schools studied, 2) a description of the Hands-On Hortscience workbook used in this study, 3) the materials and methodology used in the study, 4) the results and discussion of the research findings obtained from this study and methodology summary.

Population

The research study was in collaboration with schools in northern California and Washington during the 2004-2005 school year. Six schools participated in the study (Table 1). One Washington school participated to pilot test the curriculum for its state.

Table 1. Summary of schools, their location, number of students and grade level participating in the Hands-On Hortscience: A Problem to Solve study.

Participating School	**City and State**	**N**	**Grade Levels**
Colusa High School	Colusa, CA	31	9-12
Lindhurst High School	Olivehurst, CA	52	9-12
Nevada Union High School	Grass Valley, CA	58	9-12
Orland High School	Orland, CA	18	9-12
Red Bluff High School	Red Bluff, CA	45	9-12
Tenino High School	Tenino, WA	57	9-12

Each school site had one horticulture teacher teach two classes: the treatment group (Hands-On Hortscience) and the control group (subject matter). This minimized differences and variability in teaching skills between two teachers at one school site. Numbers of students in the control group and treatment group are in Table 2.

Table 2. Summary of students in either the control group or treatment group at each school site.

Participating School	**Total # Students (n)**	**Control Group**	**Treatment Group**
Colusa High School	31	14	17
Lindhurst High School	52	25	27
Nevada Union High School	58	32	26
Orland High School	18	12	6
Red Bluff High School	45	27	18
Tenino High School	57	37	20

Population demographics differed at each school site dramatically, including various economic levels and diverse racial backgrounds. Information concerning these differences were acquired from the 2004 State of California Academic Performance Index (API) Base School Report – Demographic Characteristics (California Department of Education, 2005) and the 2003 State of Washington School Report Card (Washington State Office of Superintendent of Public Instruction, 2005).

Economic levels were based on the standards from the National School Lunch Program (NSLP) during the 2004-2005 school year. Reduced price lunches were given to students whose families of four or more members earned less than $34,873 per year. Free lunches were given to students whose families of four or more members earned less than $24,505 per year (Witford, 2004). The number of students who were English Language Learners (English was the student's second language) was also collected.

Colusa High School, Colusa, CA

Colusa High School is a rural school in Colusa County, CA. It had approximately 390 students enrolled during the time of this study, 23% English language learners, and 33% of the student body participated in the NSLP receiving free or reduced priced school lunches. The school is comprised of primarily Caucasian or Hispanic students. The ethnic breakdown of students was as follows: 55% Caucasian, 38% Hispanic, 2% Pacific Islander, 1% Asian, and 1% American Indian or Alaska Native.

Lindhurst High School, Olivehurst, CA

Lindhurst High School is an urban school in Yuba County, CA. It had approximately 1262 students enrolled during the time of this study, 34% English language learners, and 74% of the student body participated in the NSLP receiving free or reduced priced school lunches. The ethnic breakdown of students was as follows: 38% Caucasian, 28% Hispanic, 26% Asian, 3% African American, 3% American Indian or Alaska Native, 1% Filipino, and 1% Pacific Islander.

Nevada Union High School, Grass Valley, CA

Nevada Union High School is an urban school in Nevada County, CA. It had approximately 2678 students enrolled during the time of this study, 1% English language learners, and 7% of the student body participated in the NSLP receiving free or reduced priced school lunches. The school was comprised of primarily Caucasian students. The ethnic breakdown of students was as follows: 91% Caucasian, 4% Hispanic, 2% American Indian or Alaska Native, and 1% Asian.

Orland High School, Orland, CA

Orland High School is an urban school in Glenn County, CA. It had approximately 634 students enrolled during the time of this study, 9% English language learners, and 40% of the student body participated in the NSLP. The school was comprised of primarily Caucasian or Hispanic students. The ethnic breakdown of students was: 59% Caucasian, 37% Hispanic, 3% Asian, and 1% African American.

Red Bluff High School, Red Bluff, CA

Red Bluff High School is an urban school in Tehama County, CA. It had approximately 1747 students enrolled during the time of this study, 2% English language learners, and 34% of the student body participated in the NSLP receiving free or reduced priced school lunches. The ethnic breakdown of students was: 74% Caucasian, 17% Hispanic, 4% American Indian or Alaska Native, 1% Asian, and 1% African American.

Tenino High School, Tenino, WA

Tenino High School is an urban school in Thurston County, WA. It had approximately 492 students enrolled during the time of this study, 1% English language learners, and 50% of the student body participated in the NSLP receiving free or reduced priced school lunches. The ethnic breakdown of students was as follows: 74% Caucasian, 17% Hispanic, 4% American Indian or Alaska Native, 1% Asian, and 1% African American.

Objectives

Objective 1: To develop a Hands-On Hortscience horticulture science workbook for high school agriculture teachers to integrate into the classroom agriscience curriculum.

Curriculum

The horticulture curriculum is based on the California Agriculture Content Standards Grades 9-12 (Boyd, 1999) from the collaborative effort involving the California Agricultural Teachers Association; California State Department of Education, High School Division; and the Stanislaus County Office of Education, Agricultural Education Tech Preparation.

The Agriculture Education Content Standards are designed to provide a basis for instruction and student assessment in secondary agriculture programs. The curriculum standards are written in terms of higher-order thinking and performance-oriented outcomes. Examples of work that students should be able to accomplish are included and are intended to provide instructors with examples of hands-on learning activities to promote the attainment of a given standard. These examples typically integrate specific performance standards as well as career and core academic performance standards.

The Ornamental Horticulture Advanced Cluster is a subset of the California Agriculture Content Standards (Boyd, 1999) which prepares students for careers in the nursery, landscaping and floral industries and is typically taught in the second or third year of a student's agriculture program. The standards in this cluster include topics in plant identification, plant physiology, soil science, plant reproduction, nursery production, floriculture, and landscaping design, installation and maintenance.

In addition, all participating schools follow the Science Content Standards for California Public Schools, Kindergarten Through Grade Twelve (Bruton and Ong, 2000), which represents the content of science education and includes the essential skills and knowledge students will need to be scientifically literate citizens in the twenty-first century. The standards for grades nine through twelve are divided into four content strands: physics, chemistry, biology/life sciences, and earth sciences. An Investigation and Experimentation strand describes a progressive set of expectations for each grade from kindergarten through grade eight, and one set of Investigation and Experimentation standards is given for grades nine through twelve (Table 3).

Table 3. The California Science Content Standards for public school students in grades 9-12.

1a. Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.
1b. Identify and communicate sources of unavoidable experimental error.
1c. Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions.
1d. Formulate explanations by using logic and evidence.
1e. Solve scientific problems by using quadratic equations and simple trigonometric, exponential, and logarithmic functions.
1f. Distinguish between hypothesis and theory and scientific terms.
1g. Recognize the usefulness and limitations of models and theories as scientific representations of reality.
1h. Read and interpret topographic and geologic maps.
1i. Analyze the locations, sequences, or time intervals that are characteristic of natural phenomena (e.g., relative ages of rocks, locations of planets over time, and succession of species in an ecosystem).
1j. Recognize the issues of statistical variability and the need for controlled tests.
1k. Recognize the cumulative nature of scientific evidence.
1l. Analyze situations and solve problems that require combining and applying concepts from more than one area of science.
1m. Investigate a science-based societal issue by researching the literature, analyzing data, and communicating the findings. Examples of issues include irradiation of food, cloning of animals by somatic cell nuclear transfer, choice of energy sources, and land and water use decisions in California.
1n. Know that when an observation does not agree with an accepted scientific theory, the observation is sometimes mistaken or fraudulent (e.g., the Piltdown Man fossil or unidentified flying objects) and that the theory is sometimes wrong (e.g., the Ptolemaic model of the movement of the Sun, Moon, and planets).

This study focused on several major areas of the California Draft Agriculture Cluster Foundation Standards presently under review by the California Agriculture Teachers Association including 5.5 Soil and Water and 5.6 Plant Nutrition (California Agricultural Technology Institute, 2004) (Appendix E), and the Washington Essential

Academic Learning Requirements (EALRs) (Appendix F), targeting the Science Grade Level Expectations (GLEs) for high school students.

Hands-On Hortscience Workbook Description

Since many high school agriculture courses meet high school science graduation requirements, integrating investigation and experimentation becomes an important requirement to such classes. The Hands-On Hortscience, A Problem to Solve: The Scientific Method, Workbook (Whitcher, 2004) was written for high school teachers to provide background information to meet the California Science Content Standards through PS/CTL and subject matter teaching approaches using horticultural science activities. Horticulture teachers have many tools at their disposal, including computer laboratories, school farms, gardens, and greenhouses. Integrating computer use with greenhouse growing laboratory exercises maximizes practical, hands-on training with sophisticated data collection and analysis methods.

Units in the workbook included: Developing the Null and Alternative Hypotheses, Teaching Outlines for the Problem Solving/ Contextual Teaching and Learning Approach and the Subject Matter Approach, the California Science Content Standards, Helpful Websites for Student Research, Making a Datasheet and Graphing Data on Excel, Determining Statistical Differences in Data, and Designing a Fertilizer Trial for One Cultivar of Bedding Plants. The Hands-On Hortscience treatment group utilized real plants, potting mix, and fertilizers to design and develop greenhouse crop experiments to learn how to collect data while learning about the scientific method with a live, hands-on project. The subject matter control group was provided data from previous plant growth experiments for analysis and interpretation. Outlines for both teaching methods and suggested activities were provided in the workbook with examples and ideas for the teacher to implement in each class. The Hands-On Hortscience Workbook is presented in Appendix G.

Since investigation and experimentation activities could be started and carried out over a period of time, this allowed teachers to incorporate other educational units into their individual classes, such as plant nutrition, fertilizers, and plant growth media. Weekly data collection could provide students an opportunity to gain experience with greenhouse growing and research techniques in addition to learning the required subjects of that class.

Materials and Methods

All of the participating schools received greenhouse crop growing materials and live plants as part of the incentive for participating in the research study. Each school had an existing greenhouse near the main classroom. Each school received nine plug trays (110 or 144 cells) of bedding plants or foliage plants (Proven Winners, Sycamore, IL and Ball FloraPlant, Chicago, IL), a case of 4" geranium pots (Dillen Products, Middlefield, OH), two water breakers, a class set of 36 plastic metric rulers, one case of plastic pot labels (Pylon Plastics, Lisle, IL), ten bags of commercially prepared potting mix (five different brands totaling 27 cubic feet of soilless media), five different brands of packaged fertilizer (water soluble and timed release), three plastic measuring cups, three packets of liquid rooting hormone concentrate, two commercial horticulture product catalogs, a copy of the Hands-On Hortscience, A Problem to Solve: The

Scientific Method Workbook (Whitcher, 2004), and a copy of the General Horticulture Laboratory Manual (Reed, 1993).

Although all school sites received the Hands-On Hortscience Workbook and greenhouse materials, teachers controlled the administration of the treatment. There were several plant growth activities from which the treatment groups could choose (fertilizer and soilless media trials) and different types of plants available (flowering, foliage, and bedding plants), so each class had a unique experience. However, while each Hands-On Hortscience treatment group might have completed different activities in their high school greenhouse facilities, they were all exposed to the same areas of horticulture: plant nutrition, soilless media, data collection, and the scientific method. Students in the Hands-On Hortscience treatment group had to determine how to best evaluate data collected from the plant experiments, interpret its importance, and calculate any statistical significance.

The control groups were provided information about the scientific method through traditional educational methods (lecture, worksheets, and chapter readings) on plant nutrition from the California Draft Agriculture Cluster Foundation Standards. Analysis of data was accomplished by providing control classes with data sets from previously completed plant growth experiments. Students in the control group had to determine how to best evaluate the data, interpret its importance, and calculate any statistical significance.

A teacher questionnaire was emailed to each participating teacher to gather information about the study, the materials provided, and recommendations for improvement for future studies and materials, and any additional activities that may have branched from this study. The questionnaire is contained in Appendix D.

Objective 2: Evaluate whether the Hands-On Hortscience Program which included PS/CTL increased students' achievement test scores in both horticulture and the scientific method.

Hortscience Achievement Test

Test items were developed in accordance with California and Washington state standards for horticulture and science with input from California and Washington high school agriculture teachers who were familiar with curriculum standards and guidelines and also the depth to which content was covered at the high school level. The test instrument was reviewed by California community college horticulture faculty who made minor recommendations to improve clarity on some of the test items.

This test instrument was designed to measure horticulture science achievement, particularly with experimentation and investigation, and horticulture knowledge in plant nutrition and soilless media (Appendix B). By following the suggested course outlines from the individual state standards, test questions were determined to be fair and valid for science achievement for the states of California and Washington.

The hortscience achievement test was a multiple-choice test comprised of questions from two sources: scientific method questions and plant nutrition questions. Of the 40 questions on the test, 18 questions were about the scientific method and 22 questions covered horticulture and plant nutrition topics (fertilizers and soilless media topics made up 18 of the questions, and general horticulture had 4 questions). The test instrument was a traditional paper and pencil test where students circled the best answer to each question. Since there was a chance of students introducing transfer error between the test and an answer sheet, no answers sheets were used and each test was hand-graded, correcting only those answers circled in the answer section or clearly marked in the blank space of the test question.

The hortscience achievement test instrument was comprised of 40 questions. Tests were graded and questions were divided by type of question: 18 scientific method questions or 22 horticulture plant nutrition questions. Scientific method questions were given a raw score of 0 to 18, according to the number of correct responses. These raw scores were multiplied by a factor of 5.56 to transform the scores into a scale of 0 to 100. The 22 horticulture plant nutrition questions were given a raw score of 0 to 22, according to the number of correct responses. These raw scores were multiplied by a factor of 4.55 to transform the scores into a scale of 0 to 100. These scales reflect a more traditional scoring system, with scores on this scale easier to interpret and analyze. Erasures and multiple answers were checked to determine if there was clear indication as to the final answer. If any item was left blank or had multiple answers circled it was marked incorrect.

Objective 3: Evaluate whether students participating in the Hands-On Hortscience Program developed positive horticulture science attitudes.

Attitude Survey

The attitude survey included questions concerning attitude on a wide range of topics and was used to measure students' opinions or feelings concerning horticulture.

Questions included in this inventory were taken from existing instruments developed to test environmental attitudes for adolescents (Campbell, 1994; Flowers, 1986; Waliczek, 1997). Various statements were selected for use in this survey in order to represent a wide range of horticultural topics. This attitude survey was reworded by the researcher, California high school agriculture teachers, and California community college faculty and modified only to the extent that students with an eighth grade reading level would be able to understand and comprehend the information.

The survey included 18 statements that students rated on a three point Likert-type scale (Likert, 1967) (Appendix C). The three possible responses to each statement were 1 = Agree, 2 = Neutral, and 3 = Disagree. Student scores were tabulated by allocating points for various answers. For example, if a student answered "Agree" to a question, he/she received three points. If a student answered "Neutral", he/she received two points. One point was given to students answering "Disagree" to a question. Students with higher attitude scores had more favorable attitudes toward horticultural science. During data analysis, it was necessary to recode certain statement answers to indicate "1" as the least favorable response and "3" as the most favorable. Cronbach's alpha reliability was used to test the instrument for internal consistency (Gall et al., 1996) and rated 0.67.

Biographical Information Section

The biographical/demographic information section (Appendix C) of the survey included questions about the students' gender, ethnicity, grade, place of residence, overall grade point average, interest in the class and agriculture department, previous classes taken, and membership in an agricultural youth organization (4-H or FFA).

Pilot Test

One high school agriculture class participated in a pilot test during the spring semester of 2004 in Chico, CA. The tests were developed as typical paper and pencil tests using a multiple-choice answer format. This format was selected because it best typifies current standardized tests used by most schools. The pilot test helped determine wording of the achievement test and resulted in changing the format of question presentation from all fill-in-the-blank to simple questions. The attitude survey had a relatively high reliability of 0.67 and the hortscience achievement test had a high reliability of 0.81 (Appendices B, C, and H).

Research Design

The experiment used a causal-comparative research method with a pre-test/post-test control experimental design (McMillan and Schumacher, 2001). The experimental (Hands-On Hortscience) and control groups (subject matter) both took a pre-test at the beginning of the school year (September, 2004). The experimental groups participated in the Hands-On Hortscience Program for approximately three months. The control group learned about horticulture science and the scientific method through standard lecture and homework format. At the end of the semester (December, 2004-January, 2005), both experimental and control groups took the post-test.

Data Collection

Pre-tests were administered in September, 2004 by the cooperating agriculture teachers. The teachers administered all post-tests in December, 2004 or January, 2005. Each time the test was administered, it contained the Hortscience Achievement Test

(Appendix B) and an attitude survey instrument (Appendix C). To maintain confidentiality, surveys and tests were coded with a number corresponding to each school site and teacher. The codes included parts of the students' school identification number and class number. Students without signed consent forms or signed personal assent forms (Appendix A) did not complete any part of the survey or achievement test.

The parental consent and participant assent forms, attitude surveys, and coded tests were all stored at California State University, Chico in the College of Agriculture. Participants without both a pre-test and post-test were dropped from the study. Names of the participants were not nor will be published, printed, or made available to any persons for any reason.

Data Analysis

The attitude survey, including the biographical section, and the Hortscience Achievement Test were hand-entered into Microsoft® Excel 2002 for Windows™ XP Professional (Microsoft Corporation, 2002) for manipulation and scoring.

All data were entered into the Statistical Package for the Social Sciences (SPSS®) for Windows™ Version 11.0.1 (SPSS, 2001) and JMP IN™ Statistical Discovery Software (Sall et al., 2005) Version 5.1 spreadsheets for evaluation. All missing scores were coded as missing values. Paired samples t-tests were used to test for statistically significant differences between pre-tests and post-tests and Least Squares Tukey-Kramer Honestly Significant Difference (HSD) was used to test for significantly different rankings on effects tests. The confidence interval of alpha was set *a priori* at 0.05.

The SPSS® procedure "Reliability Analysis" was used to determine the stability of the scientific method and horticulture plant nutrition achievement and attitude scores and the internal consistency of the instruments.

The SPSS® procedure "Frequencies" was used to determine the descriptive statistics of the data including frequencies, percentages, and central tendencies. In additional comparisons of demographic information, multivariate ANOVA in JMP IN™ were used.

The SPSS® procedure "General Linear Model – Univariate" was used to covariate the pre-test out of the analysis to account for any initial differences that may have existed among the groups based on school site, grade, gender, ethnicity, and where students lived.

Results and Discussion

This section contains data analyses testing the effectiveness of the Hands-On Hortscience problem solving teaching method on student achievement in horticulture science, particularly the scientific method and horticultural plant nutrition. The sample description and findings related to each objective and hypothesis will be presented.

Description of the Sample

The target population for this study was ninth, tenth, eleventh, and twelfth grade high school students in northern California and Washington. The respondents represented a sample of 261 students who completed both the pre-test and post-test instruments. The SPSS® procedure "Frequencies" was used to determine the descriptive statistics of the data including frequencies, percentages, and other distributions of the population. The grade distribution for students who completed the pre-tests and post-tests instruments is outlined in Table 4. There were similar numbers of sophomores in both groups but more than twice the number of freshmen and a third less juniors in the control group. There was a slightly higher population of males in the study than females. Males represented 54% of the population while 46% were female (Table 5). There were more males in the control group.

Table 4. Summary of demographic data of students participating in the Hands-On Hortscience, A Problem to Solve: The Scientific Method: Grade of respondents.

Groups	N	Percentage of Total Population
Experimental subtotal	114	43.7 %
Freshmen	24	9.1 %
Sophomores	45	17.3 %
Juniors	29	11.2 %
Seniors	16	6.1 %
Control subtotal	147	56.3 %
Freshmen	65	25.0 %
Sophomores	46	17.7 %
Juniors	22	8.6 %
Seniors	14	5.0 %
Total Population	261	100 %

Table 5. Summary of demographic data of students participating in the Hands-On Hortscience, A Problem to Solve: The Scientific Method: Gender of respondents.

	Gender	N	Percentages
Experimental	Female	53	20.3 %
	Male	61	23.4 %
Control	Female	66	25.3 %
	Male	81	31.0 %
Total		261	100 %

Ethnicity was also determined in the biographical/demographics section of the attitude survey. The ethnicity breakdown was similar between the experimental and control groups (Table 6) with the exception of “Other”, where twice as many students responded in the control group.

Table 6. Summary of demographic data of students participating in the Hands-On Hortscience, A Problem to Solve: The Scientific Method: Ethnicity of respondents.

	Ethnicity	**N**	**Percentages**
Experimental	African American	4	1.5 %
	Asian	4	1.5 %
	Caucasian	75	29.0 %
	Hispanic	17	6.6 %
	Other	14	5.4 %
Control	African American	4	1.5 %
	Asian	6	2.3 %
	Caucasian	82	31.7 %
	Hispanic	18	7.0 %
	Other	35	13.5 %
Total		261	100 %

Students were asked what type of surroundings they were raised in most of their lives (Table 7). Twice the students in the control group were raised in urban or suburban environments with both treatments having similar numbers of students living in rural surroundings. When asked about their overall grade point average from their last semester report card (Table 8), the control group had over a third more students earning grade point averages of 3.00-4.00 over the treatment group. Students reporting a grade point average of 2.00 and below were similar for both groups.

Table 7. Summary of demographic data of students participating in the Hands-On Hortscience, A Problem to Solve: The Scientific Method: “In what type of surroundings have you been raised in most of your life?”

	Answer	**N**	**Percentages**
Experimental	Rural (agriculture)	59	23.7 %
	Rural (non-agriculture)	29	11.7 %
	Suburban	10	4.0 %
	Urban	9	3.6 %
Control	Rural (agriculture)	52	21.0 %
	Rural (non-agriculture)	42	17.0 %
	Suburban	25	10.1 %
	Urban	22	8.9 %
Total		248	100 %

Table 8. Summary of demographic data of students participating in the Hands-On Hortscience, A Problem to Solve: The Scientific Method: “What was your overall grade point average in high school from your last report card?”

	Answer	**N**	**Percentages**
Experimental	3.50-4.00	9	3.7 %
	3.00-3.49	25	10.2 %
	2.50-2.99	32	13.0 %
	2.00-2.49	34	13.8 %
	1.99 or below	12	4.9 %
Control	3.50-4.00	22	9.0 %
	3.00-3.49	32	13.0 %
	2.50-2.99	37	15.0 %
	2.00-2.49	31	12.6 %
	1.99 or below	12	4.8 %
Total		246	100 %

The control group had a greater number of 15-year-olds than the experimental group and fewer 16-year-olds but had a similar proportion of 17- and 18-year old students (Table 9).

Table 9. Summary of demographic data of students participating in the Hands-On Hortscience, A Problem to Solve: The Scientific Method: "What is your age?"

	Answer	**N**	**Percentages**
Experimental	15 or younger	55	21.1 %
	16	40	15.3 %
	17	18	6.9 %
	18 or higher	1	0.4 %
Control	15 or younger	104	39.8 %
	16	25	9.6 %
	17	16	6.1 %
	18 or higher	2	0.8 %
Total		261	100 %

Objective 1

The first objective was to develop the Hands-On Hortscience horticulture science workbook for high school agriculture teachers to integrate into the classroom agriscience curriculum (Whitcher, 2004) (Appendix G). The workbook included 8 units that emphasized the scientific method, investigation and experimentation, and related exercises and references.

The California and Washington state science experimentation and investigation standards were incorporated into the workbook. For instance, making a datasheet and graphs on Microsoft® Excel required students to evaluate the scientific design process used to develop and implement solutions to problems or challenges; research, implement, and document a scientific design process used to solve a problem or challenge; define the problem; scientifically gather information and collect known empirical data; explore ideas and make a plan; scientifically test solutions; evaluate possible solutions to the problem; and evaluate the reason(s) for the effectiveness of a solution to a problem or challenge. These suggested processes and others from additional resources (Websites, reference texts, and journals) were incorporated into the workbook.

State science standards were incorporated into the workbook with background discussion sections and outlines of both the Hands-On Hortscience or subject matter approaches to teaching. Examples of how to achieve the standards were provided as individual units in the workbook. One activity required all students in both control and treatment groups to develop the null and alternative hypothesis and locate background resources for a scientific research paper with internet searches. Another activity required all students to enter data on Microsoft® Excel in a datasheet they developed, create scatterplot graphs, and determine if the data was significant by evaluating the data and analyzing the p-value. Each activity in the workbook included descriptions of the standards focus areas, the objectives of each unit, an introduction, and materials and procedures necessary to complete the activity. While most activities could be started in a typical hour-long class period, plant growth experiments designed by the Hands-On Hortscience treatment group would require up to three days of preparation in the school greenhouse with additional class time devoted to experimental research. High school agriculture teachers are recommended to spend 10 class days on plant nutrition, soils, and the scientific method (Boyd, 1999) so this research did not take away class time dedicated to additional class unit requirements.

The Hands-On Hortscience activities were designed to supplement already existing curricula and to be used by teachers to enhance investigation and experimentation in a fun, hands-on method in the school greenhouse with live plants.

Teachers guided their students which experiments to do first, and all schools had the same materials and supplies to provide for student experimentation. The control group used the plant growth data tables in the Hands-On Hortscience Workbook in lieu of working with live plants and designing any actual experiments.

Objective 2

The second objective was to evaluate whether students participating in either the Hands-On Hortscience or subject matter teaching groups had increased achievement test scores in both horticulture and the scientific method. These variables were measured with a hortscience achievement test and scored by hand and evaluated with SPSS® and JMP IN™ statistical software.

Findings Related to Hypothesis One

Analysis and Results

T-tests for independent samples were used to test the first hypothesis.

H_{01}: Participation in the Hands-On Hortscience teaching method does not increase participants' knowledge of the scientific method, investigation and experimentation.

The students were given 18 questions and asked to select the best answer. The possible scores ranged from 0 to 100, with high scores ranging from 80-100, good scores ranging from 60-79, and poor scores ranging from 0-59. Cronbach's alpha reliability test showed the instrument to have high internal consistency with a reliability score of 0.81 (Appendix H). Comparisons were made between the pre-test and post-test of the experimental (Hands-On Hortscience) group and the control (subject matter) group, which did not participate in the greenhouse plant growth experiments (Tables 10 and 11). It is important to note that no significant differences existed on the pre-test between the two groups indicating that both groups had similar horticulture science knowledge (Table 10) at the onset of the comparisons.

Table 10. T-test for independent sample analyses comparing the pre-test scientific method test scores of the Hands-On Hortscience experimental group to the pre-test scientific method test scores of the subject matter control group.

Treatment	**N**	**Mean Score**[b]	**Standard Deviation**	**df**	**t**	**Sig.**[a]
Experimental	114	40.0	17.27	1	-0.466	0.6416
Control	147	39.0	17.00			

[a] Equal variances assumed.
[b] Possible scores ranged from 0 to 100.

Table 11. T-test for independent sample analyses comparing the post-test scientific method test scores of the Hands-On Hortscience experimental group to the post-test scientific method test scores of the subject matter control group.

Treatment	**N**	**Mean Score**[bc]	**Standard Deviation**	**df**	**t**	**Sig.**[a]
Experimental	114	57.8a	19.21	1	-3.197	0.0016
Control	147	50.0b	19.82			

[a] Equal variances assumed.
[b] Possible scores ranged from 0 to 100.
[c] Levels not connected by the same letter are significantly different, Tukey-Kramer (HSD).

However, significant differences were present on the post-test scores when the two groups were compared. The experimental group had higher overall scientific method test score achievement than the control group by an average of 7.8 points (Table 11) (p=0.0016).

T-tests for paired samples were used to compare the pre-tests to the post-tests of the experimental and control groups in scientific method test question achievement (Table 12). The statistical analyses revealed that statistically significant differences existed at the p=0.0001 level between the pre-tests and post-tests of both the experimental and control groups. The experimental group had improved their scores after participating in the Hands-On Hortscience Program by 17.8 points. In comparison the control group gained only 11 points from pre-test to post-test. With this data and that found in Table 11, we reject the null hypothesis, participation in the problem solving teaching method increased participants' knowledge of the scientific method, including investigation and experimentation.

Table 12. T-test for paired sample analyses comparing the pre-test scores to the post-test scores of the experimental group and the control group.

Treatment	**Test Variable**	**N**	**Mean Score**[b]	**Standard Deviation**	**df**	**t**	**Sig.**[a]
Experimental	Pre-test	114	40.0	17.00	113	-11.19	0.0001
	Post-test	114	57.8	19.21			
Control	Pre-test	147	39.0	17.27	146	-6.424	0.0001
	Post-test	147	50.0	19.82			

[a] Equal variances assumed.
[b] Possible scores ranged from 0 to 100.

Analyses of variance (ANOVA) were used to analyze the differences between school, gender, ethnicity, where the students lived, school attended, grade point average, grade, age, number of science classes taken, number of agriculture classes taken, and active membership in a youth organization (4-H or FFA) on horticulture science achievement post-test scores. Only those analyses that showed statistically significant differences are discussed in this section.

A one-way ANOVA was used to determine the effect of school on post-test scores and was determined to be significant (p=0.0001) (Table 13). Since treatment effects were already found to be significant, a two-way ANOVA comparing post-test scores of all participating students (experimental and control groups) by school was analyzed for the scientific method test question achievement. One school was found with statistically higher scores, Nevada Union (Table 14) (p=0.0255). All of the experimental groups in each school were significantly high, and with the exception of Lindhurst and two control groups (Nevada Union and Orland) ranked in the top six post-test positions. Interestingly, the Orland experimental group scored lower than the Orland control group while the Nevada Union experimental and control groups scored comparably on their post-tests (difference of 1.16 points). Adjustment for multiple comparisons between groups was done with Tukey-Kramer HSD. This difference between schools could be due to teaching techniques or teacher background in the subject area that would influence the acceptance of the material and raise or lower the excitement level of the students (Drew, 1993; Kauchak et al., 1978).

Table 13. ANOVA comparing the post-test scores of all participating schools on scientific method test question achievement.

High School	N	Mean Score[ab]	Standard Deviation	df	F	Sig.
Colusa	31	46.8b	18.48			
Lindhurst	52	44.5b	20.39			
Nevada Union	58	69.5a	14.37	5	14.94	0.0001
Orland	18	57.5ab	15.02			
Red Bluff	45	54.5b	17.37			
Tenino	57	46.8b	18.59			

[a] Possible scores ranged from 0 to 100.
[b] Levels not connected by the same letter are significantly different, Tukey-Kramer (HSD).

Table 14. Two-way ANOVA comparing the school by treatment interaction effects on post-test scores of all participating schools on scientific method test question achievement.

High School	Treatment	Least Squares Mean[ab]	df	F	Sig.
Nevada Union	experiment	70.14a			
Nevada Union	control	68.98a			
Orland	control	58.84ab			
Colusa	experiment	56.91ab			
Red Bluff	experiment	56.22ab			
Tenino	experiment	56.16ab	5	2.61	0.0255
Orland	experiment	54.67abcd			
Red Bluff	control	53.33bc			
Lindhurst	experiment	49.63bcd			
Tenino	control	41.78bcd			
Lindhurst	control	38.92cd			
Colusa	control	34.55d			

[a] Possible scores ranged from 0 to 100.
[b] Levels not connected by the same letter are significantly different.

In general, multiple comparisons tests for means have the same underlying assumptions as ANOVA (population normality and homogeneity of variance) (Zar, 1999). Although the Tukey test appears to be robust with respect to departures from these assumptions, the robustness of each of the above procedures is not well-known, with adverse effects on both Type I and Type II errors possible if the assumptions are greatly violated (Keselman, 1976).

The Tukey-Kramer HSD uses the distribution of the maximum range among a set of random variables (Sall et al., 2005) and is a method that modifies tests to control for an overall error rate. The major drawback of a multiple comparison procedure with a low, controlled per-comparison error rate is a high probability of declaring at least one pair of means significantly differently when running multiple comparisons (Ott and Longnecker, 2001). It is an advantage for scientists to have a way to quickly look through data and immediately compare group means through Tukey lettering; group levels not connected by the same letter as deemed by Tukey-Kramer HSD as significantly different.

Least squares means are predicted values from the specified model across the levels of a categorical effect where the other model factors are controlled by being set to neutral values. The neutral values are the sample means (possibly weighted) for regressors with interval values, and the average coefficient over the levels for unrelated nominal effects (Sall et al., 2005).

Least squares means are the values that allow one to see which levels produce higher or lower responses, holding the other variables in the model constant. Least squares means are also called adjusted means or population marginal means and are the statistics that are compared when effects are tested; they partition the variability from the model into the effects measured. They might not reflect typical real-world values of the response if the values of the factors do not reflect prevalent combinations of values in the real world. Least squares means are useful as comparisons in experimental situations.

Comparisons of student ethnicity and number of free/reduced lunches by school showed that Nevada Union had the lowest numbers of free/reduced lunch program participants (7%) while Lindhurst had the highest (74%). Studies on students participating in a free/reduced lunch program show many to be "low achievers" who do not compare to those students in middle to upper class (Clark, 2002)

Post-test scores were found to be significant by ethnicity (Table 15) with a one-way ANOVA (p=0.0001). Caucasian students had the highest achievement test scores, leading all other ethnic groups by a margin of approximately 7-19 points.

Table 15. ANOVA comparing the post-test scores of students with varying ethnic backgrounds on scientific method test question achievement.

Ethnicity	**N**	**Mean Score**[ab]	**Standard Deviation**	**df**	**F**	**Sig.**
African American	8	44.5ab	18.32			
Asian	10	38.9b	20.13			
Caucasian	157	58.3a	19.28	4	7.6460	0.0001
Hispanic	35	42.6b	21.28			
Other	49	50.7ab	15.75			

[a] Possible scores ranged from 0 to 100.
[b] Levels not connected by the same letter are significantly different.

It should be noted that there were very few numbers of African American and Asian students in the sample. This may have affected those population's scores. Student high school grade point averages (out of 4.00) were analyzed in a one-way ANOVA to determine effects on horticulture science achievement (Table 16). Significance by Tukey-Kramer HSD was also determined by each grade point category (p=0.0043).

Table 16. ANOVA comparing the post-test scores of students with varying high school grade point averages on scientific method test question achievement.

Grade Point Average	**N**	**Mean Score[ab]**	**Standard Deviation**	**df**	**F**	**Sig.**
3.50-4.00	31	60.4a	20.19			
3.00-3.49	57	56.7a	19.47			
2.50-2.99	69	54.8a	17.79	4	3.9115	0.0043
2.00-2.49	65	52.3ab	19.82			
1.99 or below	24	41.0b	22.88			

[a] Possible scores ranged from 0 to 100.
[b] Levels not connected by the same letter are significantly different.

Not surprisingly, the students earning the highest grade point averages scored the highest on the scientific method achievement test. Since grade point average was found to be significant, grade in school was also analyzed with multiple comparisons performed by Tukey-Kramer HSD (Table 17). The upperclassmen were found to have higher scientific method test achievement than freshman students (p=0.0002), scoring up to 11.7 more points on test questions.

Table 17. ANOVA comparing the post-test scores of students from four grade levels on scientific method test question achievement.

Grade Level	**N**	**Mean Score**[ab]	**Standard Deviation**	**df**	**F**	**Sig.**
Freshman	89	46.0b	19.05			
Sophomore	91	57.7a	19.06	3	6.6832	0.0002
Junior	51	56.6a	20.10			
Senior	29	56.8a	19.22			

[a] Possible scores ranged from 0 to 100.
[b] Levels not connected by the same letter are significantly different.

Interaction effects were tested using univariate ANOVA for both the experimental group (Hands-On Hortscience) and the control group (subject matter approach). Table 18 shows the interaction effects between grade in school and treatment method on the post-test scores on hortscience achievement. There were statistically significant findings on post-test scores at the $p=0.0037$ level. Seniors in the Hands-On Hortscience experimental group scored nearly 8 points higher than juniors in the experimental group, over 12 points higher than sophomores in the experimental group, and almost 16.5 points higher than freshmen in the experimental group (Table 18). Seniors in the experimental group scored slightly over 25 points more than seniors in the control group, which had the lowest achievement test scores of all study groups.

Table 18. Two-way ANOVA comparing the grade in school by treatment interaction effects on post-test scores of all participating schools on scientific method test question achievement.

Grade in School	**Treatment**	**Least Squares Mean[ab]**	**df**	**F**	**Sig.**
Senior	experiment	68.11a			
Junior	experiment	60.20ab			
Sophomore	control	59.47ab			
Sophomore	experiment	55.97ab	3	5.818	0.0037
Junior	control	51.81abc			
Freshman	experiment	51.67abc			
Freshman	control	43.88c			
Senior	control	42.77bc			

[a] Possible scores ranged from 0 to 100.
[b] Levels not connected by the same letter are significantly different.

Statistically different findings were also found on post-test scores between students who had taken several science classes previously (Table 19). Students who had taken 3 or 2 science classes had higher post-test scores compared to students enrolled in 1 or none (p=0.0001). Due to the low numbers of students taking 4 or more science classes, these data had a larger standard deviation compared to the others. It should not be surprising that students with the greatest science background had the highest achievement. Connecting science to hands-on agriculture has been shown to increase student achievement, in particular with plant science (Roegge and Russell, 1990; Rothenberger and Stewart, 1995).

Table 19. ANOVA comparing the post-test scores of students with varying numbers of high school science classes on scientific method test question achievement.

High School Science Classes	**N**	**Mean Score[ab]**	**Standard Deviation**	**df**	**F**	**Sig.**
4 or more	6	65.8ab	14.67			
3 or 2	66	60.7a	16.73	3	9.3125	0.0001
1	101	54.8a	22.28			
None	88	45.6b	16.60			

[a] Possible scores ranged from 0 to 100.
[b] Levels not connected by the same letter are significantly different.

Students who listed school/classes for their horticulture resource had the highest mean scores for the post-test (Table 20). This included both the experimental and control group participants. Interestingly, the television resource group received the lowest scores, approximately 12 points lower than the school/classes response (p=0.0001). The internet did not have many responses (N=24); perhaps students included internet searches and book/magazines under the school/classes answer as a whole.

Table 20. ANOVA comparing the post-test scores of scientific method test question achievement from students using various informational resources about plants and horticulture.

Horticulture Resource	**N**	**Mean Score[ab]**	**Standard Deviation**	**df**	**F**	**Sig.**
Books/magazines	22	42.0b	19.77			
Friends	14	54.4ab	23.00			
Internet	24	50.7ab	25.89	4	6.7009	0.0001
School/classes	171	57.3a	17.38			
Television	30	41.7b	19.85			

[a] Possible scores ranged from 0 to 100.
[b] Levels not connected by the same letter are significantly different.

A major component of learning is interest in the subject material (Crunkilton and Krebs, 1982; Flowers and Osborne, 1988; Krebs, 1982; Newcomb et al., 1993) so students' hortscience achievement post-test scores were compared to their feeling response about their agriculture class. Over half of those responding said they "looked forward to their class because it was fun", and earned the highest scores on their post-tests (Table 21) (p=0.0001). Perhaps working with classmates and developing a sense of belonging among peers was a motivation for being in class (Strom and Strom, 1996). While 66 respondents said "this class was boring", they did not score the lowest. Those students answering "this class relates to my personal life" had the lowest scores.

Table 21. ANOVA comparing the post-test scores of scientific method test question achievement from students with different feelings about attending their agriculture class on a daily basis.

Feeling Response	N	Mean Score[ab]	Standard Deviation	df	F	Sig.
Look forward to it, it is fun	143	58.3a	18.85			
This class is boring	66	48.2bc	19.80	3	10.34	0.0001
This class relates to my life	44	43.2c	18.14			
I love the work in this class	8	66.0ab	16.12			

[a] Possible scores ranged from 0 to 100.
[b] Levels not connected by the same letter are significantly different.

A major part of this research was teaching the scientific method. Teachers reported those students who participated in the Hands-On Hortscience experimental group created their own group data sheets, used extra class time after weekly FFA/SAE record book data entry to check and monitor their plants in the greenhouse, decided on a weekly group watering schedule, entered their weekly plant growth data on Excel, and practiced calculating means and analyzing statistical data upon completion of the experiment. Some students used their group data for the basis of a senior project report or agriscience fair project. Other students used their hortscience project for recruitment purposes at the junior high during FFA Week.

Findings Related to Hypothesis Two

Analysis and Results

T-tests for independent samples were used to test the second hypothesis.

H_{02}: Participation in the problem solving teaching method does not increase participants' knowledge of horticulture.

All students were given 22 questions about horticulture plant nutrition and asked to select the best answer. The possible scores ranged from 0 to 100, with high scores ranging from 80-100, good scores ranging from 60-79, and poor scores ranging from 0-59. Cronbach's alpha reliability test showed the instrument to have high internal consistency with a reliability score of 0.81. Comparisons were made between the pre-test and post-test of the Hands-On Hortscience experimental group who actively grew plants in the school greenhouse and the control (subject matter) group, which did not participate in any greenhouse plant growth experiments (Table 22). There was a very high significant difference between the experimental group and the control group ($p=0.0004$); therefore we reject the null hypothesis; there are increases in participants' knowledge of horticulture plant nutrition due to use of the Hands-On Hortscience problem solving method.

Table 22. T-test for independent sample analyses comparing the post-test scores of the Hands-On Hortscience experimental group to the post-test scores of the subject matter control group on horticulture plant nutrition test question achievement.

Treatment	N	Mean Score[bc]	Standard Deviation	df	t	Sig.[a]
Experimental	114	50.1a	16.80	1	-3.5945	0.0004
Control	147	42.6b	16.81			

[a] Equal variances assumed.
[b] Possible scores ranged from 0 to 100.
[c] Levels not connected by the same letter are significantly different, Tukey-Kramer (HSD).

The experimental group scored an average of 7.5 points more than the control group on the 22 horticulture plant nutrition questions. Since students in the experimental group were given soilless media and various fertilizers to experiment with, they had numerous chances to become familiar with the products and their use. The teachers reported their students used the plant nutrition products to conduct fertility trials with a single species of bedding plant, fertility trials with several cultivars of geraniums, plant growth experiments with various potting mixes used directly from the bag or amended with field soil, and calculated amounts of plants, materials (pots, labels, fertilizer), and seeds necessary for a fall plant sale. Students at several of the high schools had to develop a rotating schedule to go to the greenhouse to monitor and water the plants because it was such a popular activity.

The school that had the highest horticulture plant nutrition achievement scores was Nevada Union (Table 23). Nevada Union's students also scored the highest on the scientific method achievement test questions as well.

Table 23. ANOVA comparing the post-test scores of all participating schools on horticulture plant nutrition test question achievement.

High School	N	Mean Score[ab]	Standard Deviation	df	F	Sig.
Colusa	31	43.3b	15.36			
Lindhurst	52	44.5b	16.35			
Nevada Union	58	60.7a	15.09	5	20.62	0.0001
Orland	18	50.6ab	15.36			
Red Bluff	45	47.9b	13.36			
Tenino	57	35.9b	12.77			

[a] Possible scores ranged from 0 to 100.
[b] Levels not connected by the same letter are significantly different, Tukey-Kramer (HSD).

Objective 3

The third objective was to evaluate whether students participating in either the Hands-On Hortscience experimental group or subject matter control group were developing positive horticulture science attitudes by participating in the research study. These variables were measured with an attitude survey instrument which was scored by hand and evaluated with SPSS® and JMP IN™ statistical software. The hypotheses tested in this section were:

H_{03}: Participation in the Hands-On Hortscience Program does not increase participants' attitude toward science and school.

H_{04}: Positive effects due to participation in the Hands-On Hortscience Program do not vary due to differences in demographic variables of the participants.

Findings Related to Hypothesis Three

Analysis and Results

T-tests and ANOVA for independent samples were used to test the third hypothesis.

H_{03}: Participation in the Hands-On Hortscience Program does not increase participants' attitude toward science and school.

The students were given 18 questions and asked to select the best answer. The possible scores ranged from 0 to 144, with high scores ranging from 115-144, good scores ranging from 51-114, and poor scores ranging from 0-50. Cronbach's alpha reliability test showed the instrument to have high internal consistency with a reliability score of 0.67. Comparisons were made between the pre-test and post-test of the experimental (Hands-On Hortscience) group and the control (subject matter) group, which did not participate in the greenhouse plant growth experiments (Table 24).

Table 24. T-test for independent sample analyses comparing the post-test scores of the experimental study participants to the post-test scores of the control group on student attitude toward horticulture, science, and school.

Treatment	**N**	**Mean Score**[bc]	**Standard Deviation**	**df**	**t**	**Sig.**[a]
Experimental	114	98.9a	20.64	1	-2.9635	0.0033
Control	147	91.4b	20.22			

[a] Equal variances assumed.
[b] Possible scores ranged from 0 to 144.
[c] Levels not connected by the same letter are significantly different, Tukey-Kramer (HSD).

There was a high significant difference between the experimental group and the control group with a difference of 7.5 points (p=0.0033); therefore we reject the null hypothesis, participants' attitudes toward science and school were increased.

Attitude toward learning has been studied extensively (Allen et al., 1995; Boone and Newcomb, 1990; Cosden et al., 1999; Mabie and Baker, 1996; Migura et al., 1997; Osborne and Hamzah, 1989; Roegge and Russell, 1990). Some of the participating teachers in this study noted that more students felt challenged by the work in the experimental group so when they worked together they formed bonds and friendships during their research. This supports what the literature contends about the connection between positive attitudes and learning. When students are given a real-world problem, they respond to the challenge because they see the connection between it and their life.

The school that scored the highest attitude score was Nevada Union (Table 25) which also scored the high score by school on the scientific method achievement test (Table 13). This supports work by leading agriculture educators on the importance of attitude on student achievement and *vice versa* (Boone and Newcomb, 1990; Campbell, 1994; Flowers and Osborne, 1988; Mabie and Baker, 1996; Migura and Zajicek, 1997; Osborne and Hamzah, 1989; Roegge and Russell, 1990; Waliczek et al., 2001). When students have educational success, they feel better about themselves and what they are capable of achieving.

Table 25. ANOVA comparing the post-test scores of all participating schools on student attitude toward horticulture, science, and school.

High School	N	Mean Score[ab]	Standard Deviation	df	F	Sig.
Colusa	31	92.8b	15.37			
Lindhurst	52	95.0b	19.86			
Nevada Union	58	108.2a	16.04	5	8.699	0.0001
Orland	18	95.3ab	18.06			
Red Bluff	45	87.3b	24.82			
Tenino	57	87.4b	19.22			

[a] Possible scores ranged from 0 to 144.
[b] Levels not connected by the same letter are significantly different, Tukey-Kramer (HSD).

Findings Related to Hypothesis Four

Analysis and Results

T-tests for independent samples were used to test the fourth hypothesis.

H_{04}: Positive effects due to participation in the Hands-On Hortscience Program do not vary due to differences in demographic variables of the participants.

Of those surveyed, female students scored higher on the attitude survey than the males (Table 26). This supports previous studies (Boyer et al., 2002; Campbell, 1994; Jones et al., 1992; Waliczek et al., 2001) where females had an opportunity to explore new areas of agriculture and science and not feel threatened in a male dominated vocation. A study on incorporating a club for girls in math and science, Girls Excelling in Math and Science (GEMS) (Jones, 2002) found that female high school students who were able to study math and science in a female-only study group "without being pushed out by the boys" (Jones, 2002) had higher interests in advanced math and science courses upon entering college.

Table 26. T-test for independent sample analyses comparing the post-test scores of female students to the post-test scores of male students on student attitude toward horticulture, science, and school.

Gender	N	Mean Score[bc]	Standard Deviation	df	t	Sig.[a]
Females	119	98.8a	19.26	1	2.9667	0.0033
Males	142	91.3b	21.31			

[a] Equal variances assumed.
[b] Possible scores ranged from 0 to 144.
[c] Levels not connected by the same letter are significantly different, Tukey-Kramer (HSD).

The experimental group utilized problem solving skills that have been shown to require higher-order thinking skills (HOTS) in addition to lower-order thinking skills (LOTS) (Boone, 1990; Boone and Newcomb, 1990; Cano and Martinez, 1989; Edwards and Briers, 2000; Johnson and Chung, 1999; Kahler et al., 1988; Newcomb and Trefz, 1987; Pate et al., 2004; Smith et al., 2001) Today's learning environment is far removed from rote memorization with the presence of WWW information available around the clock. Students need to learn how to solve problems with all of the information available (Osborne, 1999).

The post-test attitude survey scores from students by grade show seniors having the highest attitudes, closely followed by sophomores (Table 27). Have senior students developed HOTS enough to most appreciate their studies, the environment, and school? Perhaps their higher attitude scores reflect how they feel about experiential learning; they have sat through more lectures and completed more worksheets than the other grades and possibly appreciate the opportunity for an inquiry-based educational experience. The ability to get hands-on experience with the physical sciences (Johnson et al., 1997) has shown similar outcomes: experiential learning results in more positive attitudes in students.

Table 27. ANOVA comparing the post-test scores of students from four grade levels on student attitude toward horticulture, science, and school.

Grade Level	**N**	**Mean Score[ab]**	**Standard Deviation**	**df**	**F**	**Sig.**
Freshman	89	87.8b	15.59			
Sophomore	91	99.1a	20.35	3	5.7323	0.0008
Junior	51	95.8ab	17.37			
Senior	29	100.3a	16.61			

[a] Possible scores ranged from 0 to 144.
[b] Levels not connected by the same letter are significantly different.

Another possibility may be that students who enroll in agriculture courses to meet their science requirements may be field-independent learners (concrete rather than abstract) and learn better through hands-on activity (Cano and Garton, 1994; Dyer and Osborne, 1996a; Dyer and Osborne, 1996b). Field-dependent learners are those who think abstractly and can succeed with little or no hands-on activity. Students who have taken 2 or 3 or more science classes had higher attitude scores than those taking one or none (Table 28). Many students learn in the abstract instead of through inquiry focused methods. Thus, there are many different ways students can learn (Gardner, 1999).

Table 28. ANOVA comparing the post-test scores of students with varying numbers of high school science classes on student attitude toward horticulture, science, and school.

High School Science Classes	N	Mean Score[ab]	Standard Deviation	df	F	Sig.
4 or more	6	108.0ab	27.83			
3 or 2	66	100.2a	16.68	3	6.4670	0.0003
1	101	96.5a	21.13			
None	88	87.6b	20.64			

[a] Possible scores ranged from 0 to 144.
[b] Levels not connected by the same letter are significantly different.

Additional Findings

Interest in agriculture is a factor in student enrollment in classes regardless of science credit. Table 29 shows the significance of attitude on retention of students in an agriculture department. Students with the greatest attitude scores were planning on returning to their agriculture classes the following year, and those students who would not be returning to that school site the following year (due to graduation, relocation or other reasons) still had higher attitude scores than those who would not be returning to the department in favor of taking other classes.

Table 29. ANOVA comparing the post-test scores of student attitude toward horticulture, science, and school of students who will take another class in the agriculture department in the upcoming year.

Enrolled in ag class next year?	N	Mean Score[ab]	Standard Deviation	df	F	Sig.
No	80	86.7b	27.83			
Yes	150	98.1a	16.68	2	9.1978	0.0001
I won’t be here next year	29	98.3a	21.13			

[a] Possible scores ranged from 0 to 144.
[b] Levels not connected by the same letter are significantly different.

Students who were enrolled in agriculture classes had varying degrees of interest in those classes that were reflected in their attitude score (Table 30). Being focused on a specific aspect of horticulture affected attitude scores, with students interested in growing foliage houseplants receiving the highest scores. The low student numbers in that treatment though may have affected the Tukey-Kramer HSD. Again, the primary interests that had strong hands-on application scored the highest while those students only enrolled to meet the science graduation requirement had the lowest attitudes (score difference was approximately 19.5 points).

Table 30. ANOVA comparing the post-test scores of student attitude toward horticulture, science, and school from students with different primary interests in their agriculture class.

Primary Interest	**N**	**Mean Score[ab]**	**Standard Deviation**	**df**	**F**	**Sig.**
Floral design	23	101.9ab	14.96			
Growing houseplants	14	107.7ab	15.41			
Growing landscape plants	39	94.8ab	23.02	4	5.9894	0.0001
Learning about all plants	77	99.0a	17.12			
Meet grad. requirement	106	88.1b	22.11			

[a] Possible scores ranged from 0 to 144.
[b] Levels not connected by the same letter are significantly different.

A follow-up question was raised about why students' attitudes may be high (Table 31). With the question "What do you enjoy the most about this class", the greatest number of students said it was fun and they got to work with others. While this reason was most touted, the answer that received the highest attitude score from responding students was that the hands-on projects were most enjoyable, supporting similar results of student interest, self-worth, and self-validation (Allen et al., 1995; Boyer et al., 2002; Rothenberger and Stewart, 1995).

Table 31. ANOVA comparing the post-test scores of student attitude toward horticulture, science, and school from students with different reasons why they enjoy their agriculture class.

What do you enjoy most about this class?	**N**	**Mean Score[ab]**	**Standard Deviation**	**df**	**F**	**Sig.**
Relates science topics	20	95.0ab	18.26			
Hands-on projects	81	99.6a	20.39	3	3.9167	0.0093
Fun/work with others	107	94.9ab	18.57			
What I learn is up to me	49	87.1b	23.54			

[a] Possible scores ranged from 0 to 144.
[b] Levels not connected by the same letter are significantly different.

Coupled with enjoyment with class activities is how students feel when they are in class (Table 32). A sense of place, safety, and caring from the agriculture teacher provides many students with a climate of compassion and security in a harsh "real world" environment beyond the school doors (Johnson and Johnson, 1990; Newman, 1999; Noddings, 1992; Slavin, 1990; Werner and Smith, 1989). Students who are challenged in their classes and see the relevance of what they are learning routinely score higher on attitude tests (Newman, 1999). All of the participating agriculture teachers in this research are active FFA advisors: coaching judging teams, Parli-Pro teams, and public speakers; managing fundraisers, community service events, and all happen to be department chairmen. Some of the comments from the agriculture teachers were about the efforts they put into their agriculture programs to serve not only their students but their community as well. One teacher said (personal communication),

"…the positive feedback I get from my community makes all of the hard work and long hours I put in with my kids worthwhile." This kind of attitude most certainly resonates to the students, making them feel special, included, and appreciated.

Table 32. ANOVA comparing the post-test scores of student attitude toward horticulture, science, and school from students with different feelings about attending their agriculture class on a daily basis.

Feeling Response	**N**	**Mean Score[ab]**	**Standard Deviation**	**df**	**F**	**Sig.**
Look forward to it, it is fun	143	100.3a	18.59			
This class is boring	66	83.1b	21.50	3	12.54	0.0001
This class relates to my life	44	92.4ab	18.50			
I love the work in this class	8	104.0a	22.12			

[a] Possible scores ranged from 0 to 144.
[b] Levels not connected by the same letter are significantly different.

Projects, hands-on activities, laboratories, and other concrete methods of instruction get students motivated and create a sense of student "buy-in" where they own the problem and have a felt need to get an answer (Dewey, 1916). Table 33 shows how learning through the context of agriculture stimulates student interest regardless of the amount of hands-on activity (note two control groups scored in the top 50% of those tested). Perhaps their agriculture teacher was dynamic, motivated, and had a fondness for teaching that affected student attitude (Drew, 1993). It is not surprising that those students in the subject matter control group who said their agriculture class was boring scored the lowest; their lack of interest or attention to the subject material significantly dropped their attitude scores.

Students who have considered agriculture or horticulture as a career upon graduation from high school expressed the most interest and positive attitudes among all surveyed (Table 34). The majority of respondents to "no, they had other career interests" still had attitudes that ranked "good" on the attitude scale.

Table 33. Two-way ANOVA comparing the interaction effects between treatment by feeling about attending an agriculture class on post-test scores of student attitude toward horticulture, science, and school.

Treatment	**Feeling Response**	**Least Squares Mean**[ab]	**df**	**F**	**Sig.**
Experiment	I love the work in this class	117.33a			
Experiment	Look forward to it, it is fun	101.50a			
Control	Look forward to it, it is fun	98.99a			
Control	I love the work in this class	96.00ab	3	4.0175	0.0081
Experiment	This class is boring	95.13a			
Control	This class relates to my life	94.00a			
Experiment	This class relates to my life	89.50ab			
Control	This class is boring	76.65b			

[a] Possible scores ranged from 0 to 144.
[b] Levels not connected by the same letter are significantly different.

Table 34. ANOVA comparing the post-test scores of student attitude toward horticulture, science, and school from students with thoughts about becoming a professional nurseryman or florist.

Want to be a professional nurseryman or florist?	**N**	**Mean Score**[ab]	**Standard Deviation**	**df**	**F**	**Sig.**
Yes, I love plants & outside	14	110.6a	19.38			
Yes, only in a nursery	4	85.0ab	10.52			
Yes, as a florist	19	101.1ab	17.12	4	4.1946	0.0016
No, but plants are interesting	39	100.2ab	18.10			
No, I have other interests	185	91.9b	21.01			

[a] Possible scores ranged from 0 to 144.
[b] Levels not connected by the same letter are significantly different.

An important aspect of agriculture education is preparation for careers upon graduation. Students who are involved with their agriculture classes typically apply what they are learning to their FFA/SAE program. Knowing that if students value their educational experiences, they should be paying attention to how those experiences prepare them for work after high school. When asked if "classes are meaningful to your career", student response was correlated depending on relevance (Table 35). There are definite significant differences between students who are applying what they are learning and those who see no meaning or relevance to future careers, resulting in students that are fully interested and engaged in their studies and that they are applying everything to their career, shown by higher attitude scores.

Amazingly some students do not realize that even if they will never farm or live on a ranch, they will forever be taxpayers and consumers of agricultural goods. Knowing the basis behind commercial agriculture and horticulture's production decisions can only improve a student's use of and attitude toward agricultural technology in a home setting.

Table 35. ANOVA comparing the post-test student attitude scores toward horticulture, science, and school from students asked if their high school classes are meaningful to them and their career interests.

Are your classes meaningful to your career?	**N**	**Mean Score**[ab]	**Std. Dev.**	**df**	**F**	**Sig.**
Yes, I'm applying everything	79	99.6a	22.39			
Yes, some are not relevant	60	98.0a	17.33			
Yes, ag classes are most beneficial	44	93.5ab	20.53	4	3.8476	0.0047
No, nothing is relevant to my career	70	87.8ab	18.88			
No, just here to get my diploma	8	88.5b	28.32			

[a] Possible scores ranged from 0 to 144.
[b] Levels not connected by the same letter are significantly different.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Purpose of the Study

The purpose of this study was to assess the effects of teaching method on investigation and experimentation achievements of high school students enrolled in agriculture courses and evaluate the attitudes of students upon completion of the teaching unit. The objectives of this study were to 1) develop Hands-On Hortscience horticulture science workbook for high school agriculture teachers to integrate into the classroom agriscience curriculum, 2) evaluate whether the Hands-On Hortscience Program which included PS/CTL increased students' achievement test scores in both horticulture and the scientific method, and 3) evaluate whether students participating in the Hands-On Hortscience Program developed positive horticulture science attitudes.

Summary of the Review of the Literature

Students construct their own knowledge by experiencing, thinking, and applying. Only with experience can students truly learn, and with learning comes awareness and interest in the world around them.

Called experiential learning, hands-on learning, authentic learning, and contextual teaching and learning, problem solving builds or constructs knowledge (constructivism) and has been the focus of education since the days of John Dewey, Jean Piaget, Jean-Jacques Rousseau and Lev Vygotsky (Doolittle and Camp, 1999; Finkel, 2000). Dewey's conclusion about intelligence and thinking (published in 1916) come down to a provoking thought:

> …no thought, no idea, can possibly be conveyed as an idea from one person to another. When it is told, it is, to the one to whom it is told, another given fact, not an idea. The communication may stimulate the other person to realize the question for himself and to think out a like idea, or it may smother his intellectual interest and suppress his dawning effort at thought. But what he directly gets cannot be an idea. Only by wrestling with the conditions of the problem at first hand, seeking and finding his own way out, does he think.

Dewey's whole philosophy of education flows from this conclusion that people learn only by thinking for themselves and that in modern education comes from teachers setting up learning experiences for their students where learning may occur (Finkel, 2000).

High school vocational agriculture courses were the leaders in teaching higher order thinking skills by use of the problem solving teaching method (Boone, 1990; Crunkilton and Krebs, 1982; Flowers and Osborne, 1988; Lancelot, 1944; Newcomb et al., 1993; Phipps and Osborne, 1988). Hands-on learning through use of projects (called SAE in later years), to make connections and apply knowledge beyond the borders of the classroom has been called inquiry centered or student centered learning in the science education community (Von Secker and Lissitz, 1999). Science educators believe that the fundamentals of science must include inquiry as a base. This includes making observations, researching previous history, planning investigations, and using tools to gather and analyze data. Use of logical thinking and higher order thinking skills (analysis, synthesis and evaluation) (Bloom, 1956) lead to development of selfconfidence and interest in the sciences which ultimately leads to personal growth and achievement.

The years in adolescence can be confusing and frightening for many students. The challenges of growing up, taking on more responsibility, and caring for younger brothers and sisters occur as more parents work fulltime outside of the home. Coupled with more rigorous graduation standards, many students quickly lose interest in school if they see no connection to their own lives. Teachers need to find connections to students and provide learning experiences that are interesting, beneficial, and relevant to learning (U.S. Department of Education, 2002). Research in agriculture education has discovered that student success in the classroom increases achievement, motivates students to learn more, and improve attitudes of students while developing critical thinking skills and hands-on vocational and technical skills (Balschweid, 2002; Boone, 1988a; Cano and Martinez, 1989; Crunkilton, 1984; Dyer and Osborne, 1996b; Flowers, 1986; Flowers and Osborne, 1988; Johnson and Johnson, 1990; Johnson et al., 1997; Knobloch, 2003; Lancelot, 1944; Lohr, 1992; Newcomb et al., 1993; Osborne, 1999; Owens et al., 1999; Roegge and Russell, 1990; Stohr-Hunt, 1996). Requirements by the US Department of Education has pushed science and mathematics achievement to the forefront of education and graduation requirements, and unless teachers are willing to meet those challenges they may soon face consequences targeting their departments, budgets, and staffing.

The findings from the literature review helped determine the overall needs and objectives of the study and the direction of the hypotheses that were targeted at increasing science knowledge in a fun, interesting manner that may remain with the students for years to come.

Methodology

This study was an evaluation of the Hands-On Hortscience, A Problem to Solve: The Scientific Method Program to increase high school agriculture students' knowledge in the scientific method and horticulture plant nutrition. Attitude toward the agriculture class, science, and school were assessed prior to and immediately following the prescribed treatment. Students were pre- and post-tested during the fall of 2004 and spring of 2005. Pre-tests and post-tests were compared. A control group was selected from one of two high school agriculture courses that were taught by the same agriculture teacher from a school site. This group did not participate in the greenhouse experimental plant growth activities of the Hands-On Hortscience Program.

Sample Group

The sample included approximately 240 ninth through twelfth grade students for comparison from six different high schools in northern California and Washington. These included both control and experimental group participants. The agriculture teachers of the participating schools volunteered their students to participate in the study.

Instrumentation

The instruments used in this study contained a horticulture science achievement test (Appendix B) and a biographical information section and attitude survey (Appendix C). The students were all pre- and post-tested.

The horticulture science achievement test was divided by two types of questions: the scientific method and horticulture plant nutrition. The scientific method portion of the horticulture science achievement test contained 18 questions about hypotheses development, use of control and treatment groups, measurement error, creating graphs, data collection techniques and analysis, and statistical significance of data. The horticulture plant nutrition knowledge section of the horticulture science achievement test included 22 questions about the horticulture industry, function of soilless potting mixes, organic amendments, fertilizer analysis, essential plant nutrients, fertigation and fertilizer use, plant deficiency symptoms, and plant conduction tissues. This achievement test was used to measure students' knowledge of horticulture fertility practices, the scientific method of discovery, and research data interpretation. This test was developed from existing curriculum and content standards for high school agriculture and science courses (Boyd, 1999; Bruton and Ong, 2000; Smith, 2000).

The biographical information section of the survey included questions about the students' gender, ethnicity, grade, age, number of agriculture and science courses taken, participation in a youth agriculture association, and interest in the agriculture courses and agriculture industry. The attitude section of the survey included 18 statements which were rated on a Likert-type scale (Likert, 1967). The three possible responses to each statement were 1=”Agree,” 2=”Neutral”, and 3=”Disagree”. This survey was used to measure students' opinions or feelings about horticulture practices, learning about science, and participating in class work and was developed from existing instruments used in previous studies to test environmental attitudes (Campbell, 1994; Flowers, 1986; Waliczek, 1997).

A teacher questionnaire was also distributed to each participating agriculture teacher (Appendix D) to gather information about the educational background of each teacher, information of the treatment administration at each school, including what types of activities students participated in and how often students utilized the research materials provided. The questionnaire also asked about the value of the Hands-On Hortscience workbook and supplemental information provided to assist in setting up the study.

Conclusions

The following conclusions were based on the research and results presented in the previous chapter. Student achievement in hortscience, particularly in the scientific method and horticulture plant nutrition, are discussed, as well as attitudes toward learning horticulture and science and school in general. A summary of the results is as follows.

Hypothesis One

H_{01}: Participation in the Hands-On Hortscience Program does not increase participants' knowledge of the scientific method, investigation, and experimentation.

We reject the null hypothesis that participation in the Hands-On Hortscience Program does not increase participants' knowledge of the scientific method, investigation and experimentation. The experimental group had higher overall test achievement scores than the control group by an average of 7.8 points (Table 11) (p=0.0016). Seniors and juniors in the experimental groups performed the best (Table 18) with seniors in the control group scoring the lowest (p=0.0037). This is not surprising since the literature suggests that problem solving skills involves higher order thinking skills (Boone and Newcomb, 1990; Edwards and Briers, 2000; Flowers and Osborne, 1988) and freedoms that come with student-centered learning. Freshmen students may not be capable or ready to handle this type of learning and seniors may simply be bored with the subject matter teaching method.

The highest scores on the achievement test came from those students who looked forward to their agriculture class and thought it was fun (Table 21) (p=0.0001). Working with peers, being involved with hands-on activities, and a sense of camaraderie to work toward a common goal has all been shown to improve students' attitudes toward learning and improve test scores (Johnson et al., 1997; Strom and Strom, 1996).

Use of hands-on problems within the context of horticulture was seen by students as a fun way to incorporate science into class. Two of the cooperating agriculture teachers remarked how interested their students were in the experimental class research projects and how that class' attendance was up from the previous unit (data not collected).

Hypothesis Two

H_{02}: Participation in the Hands-On Hortscience Program does not increase participants' knowledge of horticulture plant nutrition.

We reject the null hypothesis, that participation in the Hands-On Hortscience Program does not increase participants' knowledge of horticulture. Comparisons were made between the pre-test and post-test of the experimental group which designed and executed real greenhouse plant experiments and the control group, which did not participate in any greenhouse plant growth experiments (Table 22). There were significant differences between the experimental group and the control group knowledge questions about plant nutrition and fertilizers (p=0.0004). Questions were also asked about general horticulture topics, plant anatomy, and horticulture careers. The highest horticulture plant nutrition achievement and scientific method achievement scores all came from students at Nevada Union High School, whose agriculture teacher had a M.S. degree and extensive experience in teaching horticulture science (teacher response survey).

The literature suggests that it takes as much time to prepare problem solving curriculum compared to the subject matter method (Boone, 1988b; Finkel, 2000; Flowers, 1986; Roegge and Russell, 1990; Rothenberger and Stewart, 1995) and in some cases longer (Atwell, 1987; Finkel, 2000; Seabrook, 1991). Perhaps some of the teachers who were not as proficient in horticulture misjudged the use of the resources and time necessary to plan and develop the research activities. Several of the teachers commented how excited their students were to use the greenhouse facilities "to its maximum" and have actual horticulture crop experiments growing in them. Some of the teachers have felt pressure to use their greenhouses more after not using it extensively for a couple of years and this research gave them incentive to “get back into the swing of things” (one teacher’s comment).

Hypothesis Three

H_{03}: Participation in the Hands-On Hortscience Program does not increase participants’ attitude toward science and school.

We reject the null hypothesis, participating in the Hands-On Hortscience Program does increase participants’ attitudes toward science and school. T-tests for independent samples were used to test this hypothesis comparing the post-test scores of the experimental study participants to the post-test scores of the control group on student attitude toward horticulture, science, and school (Table 24) ($p=0.0033$).

Student success in the classroom increases achievement, motivates students to learn more, and improves attitudes of students while developing critical thinking skills and hands-on vocational and technical skills (Balschweid, 2002; Boone, 1988a; Cano and Martinez, 1989; Crunkilton, 1984; Dyer and Osborne, 1996b; Flowers, 1986; Flowers and Osborne, 1988; Johnson and Johnson, 1990; Johnson et al., 1997; Knobloch, 2003; Lancelot, 1944; Lohr, 1992; Newcomb et al., 1993; Osborne, 1999; Owens et al., 1999; Roegge and Russell, 1990; Stohr-Hunt, 1996). With the requirements on schools with the influence of NCLB on state science standards and essential learnings (Appendices D and E), districts are searching for ways to motivate students to learn more and perform better on state-mandated assessment tests or else lose vital funding to districts and programs.

Motivated students enjoy school and perform well. Students who reported they liked to “plan and develop hands-on projects” as the part most enjoyed in their agriculture classes had the highest attitude scores (Table 31). The answer “this class relates science topics to my personal life” barely edged out the answer “the activities are fun and I get to work with other people”. Interestingly, the lowest scoring answer of the four questions was “what I learn is up to me” (p=0.0093).

There were also statistically significant differences between students’ attitudes when asked about how they feel about attending their agriculture class on a daily basis (Table 32) (p=0.0001). Responses from students who “wished they could stay all day, I love the work” and “I look forward to this class, it is fun” had the highest attitude scores. Students who “dread this class, it is boring” had the lowest attitude scores. In a two-way ANOVA comparing treatment to feeling response (Table 33), those students in the control group who responded “I dread this class, it is boring” had the lowest attitude scores of all interactions. This confirms what the literature shows about the connection between positive attitudes and learning (Allen et al., 1995; Boone and Newcomb, 1990; Cosden et al., 1999; Mabie and Baker, 1996; Migura et al., 1997; Osborne and Hamzah, 1989; Roegge and Russell, 1990). Some of the participating teachers noted that more students felt challenged by the work in the experimental group so when they worked together they formed bonds and friendships during their research. Students in the experimental groups learned to depend on each other where before they did not enjoy group work.

Teachers at all schools reported their students used the provided research materials (plants, soilless media, fertilizers, pots, and plant labels) to begin plant growth experiments in the experimental group classes. All experimental groups designed at least two similar plant growth studies: one study with one or more cultivars of plants receiving various levels of water soluble fertilizer, and the other experiment using the different brands of soilless media in a growth trial with different plant species. Two of the schools, Nevada Union and Tenino, reported their experimental groups used the water soluble fertilizer in a hydroponics trial comparing its needs to the soilless media trial using their own hydroponics equipment already present on site. The teacher at Tenino was so impressed with the performance of one of the brands of soilless media and decided to switch to that brand for the upcoming year's plant sales. Her students took their research data and incorporated it into Microsoft® PowerPoint (Microsoft Corporation, 2003) presentations for their class. The teacher at Colusa reported her students were not interested in the research at first but after receiving the live plants at their school site they requested to go to the library to perform internet searches on plant nutrition. The students later cleared out the old raised beds in the garden area behind the greenhouse that had been neglected; they wanted to continue growing flowers for the remainder of the semester. The Red Bluff experimental group discovered from their research they needed to repair their school greenhouse's cooling system to provide proper climate control for their plant studies. They also cleared out an old storage building for their research supplies and planned a schedule for growing vegetable transplants for their spring plant sale. They later held a plant sale and used their plants to promote horticulture and science at their school site during National FFA Week. Orland students prepared group presentations concerning their horticulture research and took the plants that they grew home. The Lindhurst students in the experimental group propagated their research plants at the conclusion of their fertility study to increase their plant numbers for a fall plant sale, generating income for student field trips to local nurseries.

Hypothesis Four

H_{04}: Positive effects due to participation in the Hands-On Hortscience Program do not vary due to differences in demographic variables of the participants.

We reject the null hypothesis; positive effects due to participation in the Hands-On Hortscience Program do vary due to differences in demographic variables of the participants.

Female students were found to have higher post-attitude scores than males ($p=0.0033$) (Table 26). Attitude post-test scores differed by 7.5 points. This confirms what has been shown in the literature from previous studies on student attitude between the sexes (Boyer et al., 2002; Campbell, 1994; Waliczek et al., 2001). In science and mathematics, females tend to perform lower than male students (American Association of University Women, 1992; National Center for Education Statistics, 2005a). Academic performance is a key measure of success in school because high performance in school opens doors to postsecondary education and to high-paying jobs. For females to have the same opportunities as males in postsecondary education and in the labor market, it is important for them to be equally well prepared academically. Overall, females have done much better than males in reading and writing, but have generally, though not always, lagged behind in science and mathematics. Concern exists that this gap in science and mathematics may give them less access to high paying jobs, although there are no data to compare this disadvantage with the possible disadvantage faced by males because of their lower reading and writing achievement (National Center for Education Statistics, 2005a).

In this study, all of the participating agriculture teachers were female. This may have contributed to the success of female students in this study, in particular the experimental group, since they had an instant role model and leader in the classroom, someone they could relate to.

Grade in school was also found to be statistically significant (p=0.0008). While there was no difference within the upper grades on attitude (sophomores, juniors, or seniors), there was a difference between the upper grades and freshmen (Table 27) who had lower attitudes (a difference in attitude score by 12.5 points). Studies concerning HOTS have repeatedly shown that students who are engaged, challenged, and allowed to be creative in their learning are successful and have higher academic performance (Cano and Martinez, 1989; Newcomb and Trefz, 1987; Smith et al., 2001). Freshmen students may still be utilizing LOTS in their first year of high school and are not prepared for the HOTS necessary in problem solving learning, especially when they are responsible for time management and outside preparation for their class research as in this study.

Using horticulture as the context for learning science may have been beneficial to freshmen students to keep them interested in the class assignments and stimulate additional interest in the class research studies.

No statistical differences were found on attitude by ethnicity or participation in a youth agriculture organization such as FFA or 4-H.

Programmatic Implications

The following recommendations for action are based on the findings and conclusions of this study.

1. The results of the study indicate that the problem solving experiments using real plants, fertilizers, and soilless media were more interesting to students and increased student achievement in horticulture and science.
2. The results of the study indicate that hands-on learning should be utilized more and subject matter methods (primarily lecturing) should be limited in use. Use of high school greenhouse facilities for student research should increase and students should be encouraged to have a research SAE.
3. The Hands-On Hortscience workbook should be modified by the researcher to include additional hortscience activities in other areas of instruction (plant propagation and genetics, biotechnology, and chemical growth control).
4. The Hands-On Hortscience workbook should be included in high school agriculture courses that have a greenhouse on site to better utilize facilities and promote experiential learning.

5. The Hands-On Hortscience workbook should be developed into a guide for students, allowing them to work through problem solving in a contextual manner in groups or paired settings.

Recommendations for Additional Research

The results of this study indicated that further research be conducted. Recommendations are as follows:

1. Replication of the research study is necessary to ensure findings are legitimate.
2. Future research should be investigated with the Hands-On Hortscience workbook with high school agriculture students and the influence of greenhouse plant growth experiments on achievement scores.
3. Additional review of the Hands-On Hortscience workbook by high school agriculture teachers and community college horticulture instructors to continually improve and revise the activities.
4. Additional testing should be conducted with a pre-test/post-test control versus experimental groups to better control external validity threats.
5. Further research should be conducted on student retention of horticulture science knowledge over time and application of problem solving strategies to other situations in horticulture.

6. Further research should be done on the effect of problem solving learning and student attendance in high school agriculture and science classes, particularly in Washington.
7. Further research should be conducted to determine how the educational background of teachers affects student learning through problem solving strategies.
8. Research groups should look closer at minority populations enrolled in agriculture courses. There are very few(Boone and Newcomb, 1990) studies that show how minority populations succeed in agriculture programs and agriculture careers even though they have no different perception toward career opportunities in the agriculture industry (White et al., 1991). This may be a recruitment tool high school teachers can use to get inner-city students involved with agriculture classes and FFA.

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APPENDIX A

PARENTAL CONSENT AND STUDENT ASSENT FORMS

Parental Consent Form (Experimental Group)

I understand that:

- My child will be taking part in a study on learning the scientific method that is being conducted by Texas A&M University and his/her school. This study will look to see how two different teaching strategies have an affect on attitudes toward horticulture, science, and school. Benefits to my child will include greenhouse production activities where he or he will have his or her own plants to keep after the study is complete.

- Approximately 500 students in 6 schools in California and Washington will be participating in this study and they will receive lessons in plant nutrition through the scientific method. A horticulture science questionnaire will be collected at the beginning and end of the semester, and each school will receive a copy of the summary of results after the study is completed.

- My child will not be obligated to answer any questions that he/she feels uncomfortable answering in the questionnaire. The tests will be encoded with a number when received to ensure confidentiality. If my child chooses not to complete the questionnaire he/she will <u>not</u> be penalized in his/her grades but will still take part in related classroom activities based on the control group's activities: traditional lecture, textbook, and worksheet format. My child will still be held responsible for learning the required material as outlined in the ag instructor's class syllabus and will be assessed by a quiz or test as deemed by the ag instructor at the completion of the unit.

- There will be no mental or physical risk to my child. No deception or coercion techniques will be used in this study and my child's survey answers will be kept completely confidential.

- Participation in this research is voluntary and I may withdraw my child from the study should I have any concerns. At any time during the course of this study I may feel free to contact the researchers – Carrie Whitcher at cwhitcher@csuchico.edu, *College of Agriculture, California State University, Chico* or Dr. Jayne M. Zajicek at j-zajicek@tamu.edu, *Department of Horticulture Sciences at Texas A&M University. College Station, TX.*

- I understand this research study has been reviewed and approved by the Institutional Review Board – Human Subjects in Research, Texas A&M University. For research related problems or questions regarding subjects' rights, the Institutional Review Board may be contacted through Dr. Michael W. Buckley, Director of Research Compliance, Office of Vice President for Research at (979) 845-8585 (email: mwbuckley@tamu.edu).

I have read and understand the explanation provided to me. I will receive a copy of this consent form. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in this study. *Please mark one of the boxes below:*

☐ *I give my permission for my child to participate in this study.*

☐ *I do not give my permission for my child to participate in this study.*

Child's name: ____

Parent or Guardian's signature: ___________________ Date: ____________________

Principal Investigator: ____________________________ Date: ___________________

Please return one copy of this form to your child's school regarding your child's participation in the school horticulture science study.

Parental Consent Form (Control Group)

I understand that:

- My child will be taking part in a study on learning the scientific method that is being conducted by Texas A&M University and his/her school. This study will look to see how two different teaching strategies have an affect on attitudes toward horticulture, science, and school. Benefits to my child will include use of Excel computer software, data entry, and data interpretation. The control group will be taught the scientific method using traditional lecture format.

- Approximately 500 students in 6 schools in California and Washington will be participating in this study and they will receive lessons in plant nutrition through the scientific method. A horticulture science questionnaire will be collected at the beginning and end of the semester, and each school will receive a copy of the summary of results after the study is completed.

- My child will not be obligated to answer any questions that he/she feels uncomfortable answering in the questionnaire. The tests will be encoded with a number when received to ensure confidentiality. If my child chooses not to complete the questionnaire he/she will <u>not</u> be penalized in his/her grades but will still take part in regular classroom activities based on traditional lecture, textbook, and worksheet format. My child will still be held responsible for learning the required material as outlined in the ag instructor's class syllabus and will be assessed by a quiz or test as deemed by the ag instructor at the completion of the unit.

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I have read and understand the explanation provided to me. I will receive a copy of this consent form. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in this study. *Please mark one of the boxes below:*

- ☐ *I give my permission for my child to participate in this study.*
- ☐ *I do not give my permission for my child to participate in this study.*

Child's name: ____

Parent or Guardian's signature: ___________________ Date: _____________________

Principal Investigator: ______________________________ Date: ____________________

Please return one copy of this form to your child's school regarding your child's participation in the school horticulture science study.

Student Assent Form (Experimental Group)

I understand that:

- ❖ I will be taking part in a study on learning the scientific method that is being conducted by Texas A&M University and my school. This study will look to see how two different teaching strategies have an affect on attitudes toward horticulture, science, and school. Benefits to me will include greenhouse production activities where I will have my own plants to keep after the study is complete.

- ❖ Approximately 500 students in 6 schools in California and Washington will be participating in this study and they will receive lessons in plant nutrition through the scientific method. A horticulture science questionnaire will be collected at the beginning and end of the semester, and each school will receive a copy of the summary of results after the study is completed.

- ❖ I will not be obligated to answer any questions that I feel uncomfortable answering in the questionnaire. The tests will be encoded with a number when received to ensure confidentiality. If I choose not to complete the questionnaire I will <u>not</u> be penalized in my grades but will still take part in related classroom activities based on the control group's activities: traditional lecture, textbook, and worksheet format. I will still be held responsible for learning the required material as outlined in the ag instructor's class syllabus and will be assessed by a quiz or test as deemed by the ag instructor at the completion of the unit.

- ❖ There will be no mental or physical risk to me. No deception or coercion techniques will be used in this study and my survey answers will be kept completely confidential.

- ❖ Participation in this research is voluntary and I may withdraw from the study should I have any concerns. At any time during the course of this study I may feel free to contact the researchers – Carrie Whitcher at cwhitcher@csuchico.edu, *College of Agriculture, California State University, Chico* or Dr. Jayne M. Zajicek at j-zajicek@tamu.edu, *Department of Horticulture Sciences at Texas A&M University. College Station, TX.*

- ❖ I understand this research study has been reviewed and approved by the Institutional Review Board – Human Subjects in Research, Texas A&M University. For research related problems or questions regarding subjects' rights, the Institutional Review Board may be contacted through Dr. Michael W. Buckley, Director of Research Compliance, Office of Vice President for Research at (979) 845-8585 (email: mwbuckley@tamu.edu).

I have read and understand the explanation provided to me. I will receive a copy of this consent form. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in this study. *Please mark one of the boxes below:*

□ *I agree to participate in this study.*

□ *I do not agree to participate in this study.*

Child's name: ____

Parent or Guardian's signature: ____________________ Date: ____________________

Principal Investigator: ____________________________ Date: ___________________

Please return one copy of this form to your school regarding your participation in the school horticulture science study.

Student Assent Form (Control Group)

I understand that:

- ❖ I will be taking part in a study on learning the scientific method that is being conducted by Texas A&M University and my school. This study will look to see how two different teaching strategies have an affect on attitudes toward horticulture, science, and school. Benefits to me will include use of Excel computer software, data entry, and data interpretation. The control group will be taught the scientific method using traditional lecture format.

- ❖ Approximately 500 students in 6 schools in California and Washington will be participating in this study and they will receive lessons in plant nutrition through the scientific method. A horticulture science questionnaire will be collected at the beginning and end of the semester, and each school will receive a copy of the summary of results after the study is completed.

- ❖ I will not be obligated to answer any questions that I feel uncomfortable answering in the questionnaire. The tests will be encoded with a number when received to ensure confidentiality. If I choose not to complete the questionnaire I will <u>not</u> be penalized in my grades but will still take part in regular classroom activities based on traditional lecture, textbook, and worksheet format. I will still be held responsible for learning the required material as outlined in the ag instructor's class syllabus and will be assessed by a quiz or test as deemed by the ag instructor at the completion of the unit.

- ❖ There will be no mental or physical risk to me. No deception or coercion techniques will be used in this study and my survey answers will be kept completely confidential.

- ❖ Participation in this research is voluntary and I may withdraw from the study should I have any concerns. At any time during the course of this study I may feel free to contact the researchers – Carrie Whitcher at cwhitcher@csuchico.edu, *College of Agriculture, California State University, Chico* or Dr. Jayne M. Zajicek at j-zajicek@tamu.edu, *Department of Horticulture Sciences at Texas A&M University. College Station, TX.*

- ❖ I understand this research study has been reviewed and approved by the Institutional Review Board – Human Subjects in Research, Texas A&M University. For research related problems or questions regarding subjects' rights, the Institutional Review Board may be contacted through Dr. Michael W. Buckley, Director of Research Compliance, Office of Vice President for Research at (979) 845-8585 (email: mwbuckley@tamu.edu).

I have read and understand the explanation provided to me. I will receive a copy of this consent form. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in this study. *Please mark one of the boxes below:*

□ *I agree to participate in this study.*
□ *I do not agree to participate in this study.*

Child's name: ____

Parent or Guardian's signature: ___________________ Date: ____________________

Principal Investigator: ____________________________ Date: ___________________

Please return one copy of this form to your school regarding your participation in the school horticulture science study.

APPENDIX B

HORTSCIENCE ACHIEVEMENT PILOT TEST, PRE-TEST, AND POST-TEST

Hortscience Achievement Test

Please read each statement and circle the best answer for each question.

1. Horticulture is the study of ___________.
   - A. floriculture
   - B. nursery plants and fruit trees
   - C. turf grass
   - D. garden vegetables
   - E. all of the above

2. Hortscience uses scientific principles to _____________________.
   - A. increase public relations
   - B. improve horticulture crops
   - C. create floral works of art
   - D. science principles aren't used in horticulture
   - E. none of the above

3. The function of potting soils or growing media is to __________.
   - A. supply water
   - B. supply mineral nutrients
   - C. support and anchor plant roots
   - D. allow gas exchange
   - E. all of the above

4. ____________ is used in the production of greenhouse potted plants in containers.
   - A. steer manure
   - B. field soil
   - C. potting soil/growing media
   - D. rock
   - E. pure sand

5. Organic amendments found in potting soils/growing media can come from __________________.
   - A. decomposed plants and animals
   - B. lumber mills
   - C. rendering factories
   - D. processed sewer sludge
   - E. all of the above

6. A hypothesis is developed in hortscience research to:
   - A. prove a theory
   - B. disprove a theory
   - C. record data from an experiment
   - D. give a best guess why something is happening
   - E. none of the above

7. Which of the following combinations are examples of organic growing media amendments?
   - A. sphagnum peat moss, perlite, vermiculite, bark
   - B. sphagnum peat moss, perlite, bark, rice hulls
   - C. sphagnum peat moss, bark, rice hulls, coir fiber
   - D. perlite, vermiculite, sand, coir fiber
   - E. vermiculite, sphagnum peat moss, bark, rice hulls

8. Why are control plants used in experiments?
   - A. we want to test how effective the control treatment is
   - B. we need a high number of replicates in our experiment
   - C. we need a baseline to compare any results we may get from our treated plants
   - D. control plants are not used in experiments
   - E. none of the above

9. An 18-6-12 fertilizer contains _________ nitrogen.
   A. 18%
   B. 6 %
   C. 12%
   D. 36%
   E. 0%

10. Why should seedlings of one species be selected to use in plant growth experiments?
   A. it is easier to identify the plants
   B. it reduces the chance of experimental error
   C. to give a hint on their final height
   D. so the plants don't fall over
   E. it doesn't matter the plant size

11. Why do researchers measure initial heights on plants in an experiment?
   A. to have something to do when the plants are small
   B. the plants will give the researcher a hint on their final height
   C. to have a baseline when determining overall height gain of the plants
   D. researches don't measure initial heights on plants
   E. none of the above

12. The best way to collect plant growth data in an experiment is to take plant measurements __________.
   A. at the beginning of the experiment
   B. at the end of the experiment
   C. at regular intervals during the experiment
   D. on plant color only
   E. we don't have to take measurements

13. ____________ is a strategy nurserymen use to remove excess fertilizers from field or potting soils.
   A. Adding gypsum
   B. Adding fertilizers
   C. Pasteurizing
   D. Leaching
   E. none of the above

14. The scientific method of experimentation generally follows this order of procedure:
   A. observation, hypothesis, testing, analysis
   B. testing, hypothesis, observation, analysis
   C. analysis, observation, testing, hypothesis
   D. observation, hypothesis, analysis, testing
   E. hypothesis, observation, testing, analysis

15. The fertilizer analysis is a three number sequence listed on a fertilizer bag that gives:
   A. pounds of N, P_2O_5, and K_2O
   B. percent of N, P_2O_5, and K_2O
   C. percent of N, P_2O_5, K_2O, and Mg
   D. percent of Mg, P_2O_5, and K_2O
   E. instructions for applying the fertilizer

16. Fertilizers that are highly soluble in water and applied as a liquid solution to plants are ___________.
   A. granular fertilizers
   B. slow release fertilizers
   C. soluble fertilizers
   D. compost
   E. steer manure

17. Complete fertilizers contain:
   - A. carbon, nitrogen, and phosphorus
   - B. magnesium, carbon, and nitrogen
   - C. magnesium, nitrogen, and phosphorus
   - D. nitrogen, phosphorus, and potassium
   - E. phosphorus, potassium, and sulfur

18. A brand of computer research software used to analyze plant growth data is ___________.
   - A. Adobe Acrobat
   - B. Excel
   - C. MS Word
   - D. Photoshop
   - E. PowerPoint

19. There are _________ essential elements or nutrients required by plants.
   - A. 13
   - B. 14
   - C. 15
   - D. 16
   - E. 17

20. Micronutrients are taken up in ____________ quantities in plants.
   - A. high
   - B. low

21. If you wanted to show plant growth data over time, which of the following would be the best choice?
   - A. graph
   - B. picture
   - C. PowerPoint slide
   - D. table
   - E. Word document

22. Knowing what the scientific literature says about plants helps us create a(n) _________ from our observations.
   - A. hypothesis
   - B. analysis of data
   - C. final science report
   - D. theory
   - E. none of the above

23. Plant nutrients such as nitrogen or potassium are called macronutrients because they are:
   - A. the most important nutrients needed
   - B. the most widely available
   - C. used in smaller quantities than other nutrients
   - D. used in greater quantities than other nutrients
   - E. none of the above

24. Why do we only use one plant species during a growth experiment?
   - A. so we can make comparisons between similar plants
   - B. to eliminate the chance of one species growing faster than another
   - C. to have similar initial heights and weights between plants
   - D. it reduces error from variability between plants
   - E. all of the above

25. What is a hypothesis based on?
   - A. a student's previous knowledge
   - B. what the literature shows
   - C. a random guess
   - D. both A and B
   - E. both A and C

26. ppm is an abbreviation for ____________________.
    A. percent per million
    B. pounds per million
    C. parts per million
    D. percentages per mile
    E. parts per mile

27. Scientists use statistical data analysis because it best shows ______________.
    A. the numbers of plants that lived
    B. the numbers of plants that died
    C. the chance that any experimental results were due to the treatment effects
    D. why they obtained the experimental results they did
    E. scientists don't use statistical data analysis

28. Liquid fertilizers can be applied through the watering hose or irrigation line. This is called:
    A. mulching
    B. chelating
    C. broadcasting
    D. fertigation
    E. leaching

29. The device that meters or injects concentrated fertilizer solution through the irrigation line is called _________.
    A. proportioner or injector
    B. proportioner or chelator
    C. injector or water breaker
    D. proportioner or water breaker
    E. none are correct

30. The nutrient deficiency that causes an overall light green or chlorotic color in plants is ____________.
    A. boron
    B. calcium
    C. copper
    D. nitrogen
    E. phosphorus

31. What are some symptoms of plants fertilized with low fertilizer rates?
    A. spindling
    B. chlorosis
    C. lack of flowering
    D. small leaf size
    E. all of the above

32. Why is it a good idea to use several replicates (many plants) in growth experiments?
    A. to eliminate experimental error
    B. to get a broad range of plant variation
    C. to keep the experiment going if plants die
    D. to better estimate the true mean or average
    E. all of the above

33. Plants require the following for life:
    A. water, oxygen, and ambient temperature
    B. water, ozone, and ambient temperature
    C. water, sodium, and nitrogen
    D. water, nitrogen, and neon
    E. all of the above

34. Sugars and starches are moved throughout the plant by ________________ tissue.
    - A. photosynthesis
    - B. vascular cambium
    - C. phloem
    - D. xylem
    - E. reproductive

35. Interpreting plant growth data is best done by ___________________________.
    - A. counting plants that died
    - B. counting plants that lived
    - C. comparing treatment results to control results
    - D. taking final weights of all plants
    - E. determining which treatment cost the least

36. Wood or ____________ is dead plant tissue that conducts water from the roots up into the plant.
    - A. photosynthesis
    - B. vascular cambium
    - C. phloem
    - D. xylem
    - E. reproductive

37. Significant experimental results occur if ___________________.
    - A. the plants end up being the tallest
    - B. the plants end up being the widest
    - C. the results were not due to chance but from the treatment effects
    - D. the results were due to chance
    - E. the treatments didn't kill any plants

38. Experiments are only valuable if they give us __________________________.
    - A. important information
    - B. plants that survive the treatments
    - C. flowering plants
    - D. information from unbiased research
    - E. information from visual observations

39. Quality potting soils should contain between _________ good quality peat moss and/or coarse bark.
    - A. 0%
    - B. 25-50%
    - C. 50-75%
    - D. 75-100%
    - E. any amount

40. The optimum complete fertilizer rate for most tropical foliage houseplants and bedding plants is:
    - A. 0 ppm
    - B. 200 ppm
    - C. 600 ppm
    - D. 1200 ppm
    - E. 2400 ppm

APPENDIX C

BIOGRAPHICAL INFORMATION SECTION AND

ATTITUDE SECTION OF THE SURVEY

Hortscience Student Information Sheet

Choose the item that best relates to you:

1. What is your gender?
    a. Female
    b. Male

2. What is your ethnicity?
    a. African American
    b. Asian
    c. Caucasian
    d. Hispanic
    e. Other

3. In what type of surroundings have you been raised in most of your life?
    a. Rural (agriculture)
    b. Rural (non-agriculture)
    c. Suburban
    d. Urban

4. What was your overall grade point average in high school from your last report card?
    a. 3.50-4.00
    b. 3.00-3.49
    c. 2.50-2.99
    d. 2.00-2.49
    e. 1.99 or below

5. What is your classification in high school?
    a. Freshman
    b. Sophomore
    c. Junior
    d. Senior

6. What is your age?
    a. 15 or younger
    b. 16
    c. 17
    d. 18 or older

7. How many science classes in high school (other than this one) have you taken?
    a. 4 or more
    b. 3 or 2
    c. 1
    d. none

8. How many agriculture classes in high school (other than this one) have you taken?
    a. 4 or more
    b. 3 or 2
    c. 1
    d. none

9. Where do you get the most information about plants and horticulture?
    a. books/magazines/journals
    b. friends
    c. internet
    d. school/classes
    e. TV

10. Will you take another class in this department next year?
    a. no
    c. I won’t be in this school next year

b. yes

11. Are you an active member of a youth agriculture association?
    a. FFA
    b. 4-H
    c. I am not an active member
    d. both FFA and 4-H
    e. other

12. What is your primary interest in this class?
    a. floral design
    b. growing houseplants or tropical foliage
    c. landscaping plants, trees, shrubs, or turf grass
    d. I enjoy learning about all types of plants
    e. I am only taking this class to meet a graduation requirement

13. What do you enjoy the most about this class?
    a. This class relates science topics to my personal life.
    b. I get to do hands-on projects that I have planned and developed.
    c. The activities are fun and I get to work with other people.
    d. It is up to me to learn and apply what I have learned to new subjects.

14. How do you feel about attending this class on a daily basis?
    a. I look forward to coming to this class, it is fun.
    b. I dread this class, it is boring.
    c. This class helps me relate what I'm learning to my personal life.
    d. I wish I could stay in this class all day, I love the work.

15. Have you ever thought about becoming a professional nurseryman or florist?
    a. Yes, I love to grow plants and love to work outside.
    b. Yes, but only in the greenhouse or nursery.
    c. Yes, but only as a floral designer in a floral shop.
    d. No, but working with plants sounds interesting.
    e. No, I have other career interests.

16. Are your high school classes meaningful to you and your career interests?
    a. Yes, I'm applying what I'm learning in all of my classes to my future career.
    b. Yes for the most part, many of my classes are not beneficial or not relevant.
    c. Yes for the most part, my ag classes are the most interesting and beneficial.
    d. No, I haven't found anything interesting or relevant to my career in my classes.
    e. No, I'm already employed and am only here to get my diploma.

17. Please describe something that you learned in this class that was meaningful to you and the situation where you learned it (subject learned, activity you did, who you worked with, etc.)

Answer the following statements by circling the number that reflects your true feelings. You have three choices:

<u>Attitude Questions</u>	**Agree**	**Neutral**	**Disagree**
1. I enjoy watching plants and flowers grow.	1	2	3
2. It is important that each student be responsible for his or her own plants.	1	2	3
3. Plants that grow in greenhouses do not need daily care.	1	2	3
4. People should plant flowers only in the spring.	1	2	3
5. We should recycle potting soil if it can be sterilized.	1	2	3
6. It is important to measure out chemicals accurately.	1	2	3
7. I enjoy and am challenged by the work in this class.	1	2	3
8. Working with plants is not a simple job and requires many skills including math, writing, and reading.	1	2	3
9. Horticulture is an important part of our economy.	1	2	3
10. Greenhouse growers have to intensely manage crops.	1	2	3
11. Plants that provide food for people are the most important types of plants to grow.	1	2	3
12. Everyone should be aware of how irrigation runoff affects groundwater.	1	2	3
13. It is more important to learn how to solve problems than to just get the correct answer on an assignment.	1	2	3
14. I learn science best with hands-on lab activities.	1	2	3
15. Plants take up mineral nutrients with their water so it is alright to over-fertilize growing media.	1	2	3
16. I would like to work in the greenhouse or nursery industry after I graduate from high school.	1	2	3
17. Horticulture can be defined as applied plant biology.	1	2	3
18. Growing plants helps me understand and learn science.	1	2	3

APPENDIX D

BACKGROUND INFORMATION SURVEY FOR COOPERATING AGRICULTURE TEACHERS

Scientific Method Research Study Questionnaire

Dear Ag Teachers,

Thank you very much for spending so much of your valuable time taking part in my research study on teaching the scientific method through problem solving and contextual teaching and learning. Now that the end of the school year is quickly approaching, I was hoping you could spend a few minutes answering some questions about the kinds of activities you had your students participate in throughout the study. The answers will help me know how to improve my hortscience workbook and to write up the report on my research. Your comments are particularly important to me since you observed the students' reactions to the activities throughout the semester.

If you would like to email this questionnaire back to me please feel free to comment directly on this document. Please remember that all names are kept confidential and will not be published or released.

Thank you again,

Carrie Whitcher

Name of school:

Number of students: Classes taught:

Ag credentials held: Science credentials held:

Other teaching credentials held:

Numbers of years teaching agriculture: Are these all in the same school?

Highest educational level attained (B.S. or B.A., M.S. or M.A., subject):

Is your school on block schedule? If yes, what is the format?

How many of your department's ag classes receive science credit? Of those, how many do you teach?

Did you use the *A Problem to Solve: The Scientific Method Hands-On Hortscience Workbook*?

If yes, was the *Workbook* helpful?

What part of the *Workbook* was the most beneficial to you?

Did you use any of the provided research materials?
If yes, which ones? Circle, underline or highlight all that apply:

rulers	plants	measuring cups	rooting hormone
potting soil	fertilizer	pots	catalogs
water breakers	pot labels	*General Horticulture Lab Manual*	

What activities did you particularly enjoy? Why?

What activities did you not enjoy? Why?

What activities did your students seem to particularly enjoy?

Do you like teaching the scientific method to students? Which method did you ultimately prefer and why?

What recommendations do you have on how to improve the suggested activities/*Workbook*?

If a *Hands-On Hortscience Student Activities Workbook* were developed, would you use it with your current curriculum?

Did you do any additional activities that were related to horticulture or the scientific method? If yes, please list additional activities or examples of these.

Was your school administration interested in your participation in this research?

Would you be interested in taking part in any additional/future Texas A&M University research projects?

Additional Comments:

APPENDIX E

CALIFORNIA DRAFT AGRICULTURE CLUSTER

FOUNDATION STANDARDS

Ornamental Horticulture and Plant Science Standards Met Through Problem Solving Teaching Methods

5.2 Plant Physiology
Students will understand the basic principles of plant physiology and growth, including photosynthesis, osmosis, transpiration, respiration, plant structure, and cell structure.
Examples of the types of work students should be able to do to meet the standard:
5.2.1 Raise various plant materials under a variety of conditions and identify the factors affecting plant growth.

3.3 Plant Physiology and Growth
Students will understand the principles of plant physiology and growth.
Examples of the types of work students should be able to do to meet the standard:
3.3.1 Describe the factors which influence plant growth including water, nutrients, light, soil, air and climate.
3.3.2 Modify the factors affecting plant growth and predict plant response.

5.5 Soil and Water
Students will understand water and soil (media) management practices.
Examples of the types of work students should be able to do to meet the standard:
5.5.1 Demonstrate an understanding of water and soil and how they affect plant growth.
5.5.2 Prepare and amend soils, implement methods of soil conservation, and evaluate results.

3.6 Soil Properties
Students will understand the relationship between soils and plant production.
Examples of the types of work students should be able to do to meet the standard:
3.6.1 Identify the basics of soil texture and structure, the types of soil, the rating procedure used.
3.6.2 Identify properties of soil that are necessary for successful crop production.

3.7 Soil Biology
Students will understand what a soil food chain is (soil biology).
Examples of the types of work students should be able to do to meet the standard:
3.7.1 Describe the impact of soil biology on the environment.

3.8 Soil Management
Students will understand the effective management practices used in tillage and soil conservation.
Examples of the types of work students should be able to do to meet the standard:
3.8.1 Describe practices necessary to effectively manage and conserve soil

through irrigation, drainage and tillage practices.

3.9 Water Management
Students will understand the effective management practices used in irrigation, drainage, watersheds, and water conservation.
Examples of the types of work students should be able to do to meet the standard:
3.9.1 Describe the practices necessary to effectively manage and conserve water.

3.11 Cultural and Harvest Practices
Students will understand crop management and production practices.
Examples of the types of work students should be able to do to meet the standard:
3.11.1 Demonstrate an understanding of local cultural techniques including monitoring, pruning, fertilization, planting, irrigation, harvest treatments, processing, packaging, and marketing practices.

3.12 Post Harvest Physiology and Marketing Practices
Students will understand post harvest plant physiology and marketing practices.
Examples of the types of work students should be able to do to meet the standard:
3.12.1 Identify post harvest treatments, processing, packaging, and marketing practices used on local crops.

5.6 Plant Nutrition
Students will understand plant nutrition practices for ornamental plants as it relates to plant growth and health.
Examples of the types of work students should be able to do to meet the standard:
5.6.1 Read and interpret fertilizer labels and use proper application practices.

5.14 Horticulture Record Keeping
Students will understand the importance of keeping records of business transactions and production records.
Examples of the types of work students should be able to do to meet the standard:
5.14.1 Maintain and complete record books, production records, and other records as needed.

3.16 Record Keeping
Students will demonstrate an understanding of the principles of record keeping utilizing a variety of methods and systems.
Examples of the types of work students should be able to do to meet the standard:
3.16.1 Explain the differences between production and financial records.

5.15 Interpersonal Leadership Development
Students will recognize the traits of effective leaders.
Examples of the types of work students should be able to do to meet the standard:
5.15.1 Participate in leadership training activities associated with the FFA

including public speaking, leading group discussions, working within a committee, conducting business meetings, and problem solving.

3.17 Interpersonal Leadership Development
Students will recognize the traits of effective leaders.
Examples of the types of work students should be able to do to meet the standard:
3.17.1 Participate in leadership training activities associated with the FFA, including public speaking, leading group discussions, working within a committee, conducting business meetings, and problem solving.

5.16 Supervised Occupational Experience Project
Students will understand the relationship between a Supervised Occupational Experience project (SOE) and their preparation for a career in agriculture.
Examples of the types of work students should be able to do to meet the standard:
5.16.1 Participate in a supervised occupational experience project employing skills and knowledge learned in the classroom.
5.16.2 Maintain an on-going record book.

3.18 Supervised Agriculture Experience Project
Students will understand the relationship between a supervised occupational experience (SOE) and their preparation for a career in agriculture.
Examples of the types of work students should be able to do to meet the standard:
3.18.1 Participate in a supervised occupational experience employing skills and knowledge learned in the classroom.
3.18.2 Maintain an on-going record book.

APPENDIX F

THE WASHINGTON ESSENTIAL ACADEMIC LEARNING REQUIREMENTS (EALRs) TARGETING THE SCIENCE GRADE LEVEL EXPECTATIONS (GLEs) FOR HIGH SCHOOL SCIENCE COURSES IN GRADES NINTH AND TENTH

Investigating Systems	GLE	9	10
	2.1.1 Questioning	**Understand how to generate and evaluate questions that can be answered through scientific investigations. W** ▪ (9, 10) Generate a new question that can be investigated with the same materials and/or data as a given investigation. ▪ (9, 10) Generate questions, and critique whether questions can be answered through scientific investigations.	
	GLE	9	10
	2.1.2	**Understand how to plan and conduct systematic and complex scientific investigations. W** ▪ (9, 10) Make a hypothesis about the results of an investigation that includes a prediction with a cause-effect reason. ▪ (9, 10) Generate a logical plan for, and conduct, a systematic and complex scientific controlled investigation with the following attributes: □ hypothesis (prediction with cause-effect reason) □ appropriate materials, tools, and available computer technology □ controlled variables □ one manipulated variable □ responding (dependent) variable □ gather, record, and organize data using appropriate units, charts, and/or graphs □ multiple trials □ experimental control condition when appropriate □ additional validity measures ▪ (9, 10) Generate a logical plan for a simple field investigation with the following attributes: □ Identify multiple variables □ Select observable or measurable variables related to the investigative question ▪ (9, 10) Identify and explain safety requirements that would be needed in an investigation.	

Investigating Systems	GLE	9	10
	2.1.3 Explaining	**Synthesize a revised scientific explanation using evidence, data, and inferential logic. W** ▪ (9, 10) Generate a scientific conclusion, including supporting data from an investigation, using inferential logic. (e.g., The fertilizer did help the plants grow faster, but had little effect on the number of seeds that germinated. With the fertilizer, the plants matured 35 days sooner than plants without the fertilizer. Almost all of the 30 seeds used germinated, 13 seeds in the fertilized soil and 14 seeds in the soil without fertilizer.) ▪ (9, 10) Describe a reason for a given conclusion using evidence from an investigation. ▪ (9, 10) Generate a scientific explanation of an observed phenomenon using given data. ▪ (9, 10) Predict and explain what logically might occur if an investigation lasted longer or changed. ▪ (9, 10) Explain the difference between evidence (data) and conclusions. ▪ (10) Revise a scientific explanation to better fit the evidence and defend the logic of the revised explanation. ▪ (9, 10) Explain how scientific evidence supports or refutes claims or explanations of phenomena.	
	GLE	9	10
	2.1.4	**Analyze how physical, conceptual, and mathematical models represent and are used to investigate objects, events, systems, and processes. W** ▪ (9, 10) Compare how a model or different models represent the actual behavior of an object, event, system, or process. ▪ (9, 10) Evaluate how well a model describes or predicts the behavior of an object, event, system, or process. ▪ (9, 10) Create a physical, conceptual, and/or mathematical (computer simulation) model to investigate, predict, and explain the behavior of objects, events, systems, or processes (e.g., DNA replication).	

	GLE	9	10
Investigating Systems	2.1.5 Communicating	**Apply understanding of how to report complex scientific investigations and explanations of objects, events, systems, and processes and how to evaluate scientific reports. W** ▪ (9, 10) Report observations of scientific investigations without making inferences. ▪ (9, 10) Summarize an investigation by describing: □ reasons for selecting the investigative plan □ materials used in the investigation □ observations, data, results □ explanations and conclusions in written, mathematical, oral, and information technology presentation formats □ ramifications of investigations to concepts, principles, and theories □ safety procedures used ▪ (9, 10) Describe the difference between an objective summary of data and an inference made from data. ▪ (9, 10) Compare the effectiveness of different graphics and tables to describe patterns, explanations, conclusions, and implications found in investigations. ▪ (9, 10) Critique a scientific report for completeness, accuracy, and objectivity.	

Nature of Science	GLE	9	10
	2.2.1 Intellectual Honesty	**Analyze why curiosity, honesty, cooperation, openness, and skepticism are important to scientific explanations and investigations. W** ▪ (9, 10) Explain why honesty ensures the integrity of scientific investigations (e.g., explanations in the absence of credible evidence, questionable results, conclusions or explanations inconsistent with established theories). ▪ (9, 10) Explain why a claim or a conclusion is flawed (e.g., limited data, lack of controls, weak logic). ▪ (9, 10) Explain why scientists are expected to accurately and honestly record, report, and share observations and measurements without bias. ▪ (9, 10) Explain why honest acknowledgement of the contributions of others and information sources are necessary (e.g., undocumented sources of information, plagiarism). ▪ (9, 10) Explain why peer review is necessary in the scientific reporting process.	
	GLE	9	10
	2.2.2	**Analyze scientific theories for logic, consistency, historical and current evidence, limitations, and capacity to be investigated and modified. W** ▪ (9, 10) Describe how a theory logically explains a set of facts, principles, concepts and/or knowledge. ▪ (9, 10) Describe a theory that best explains and predicts phenomena and investigative results. ▪ (9, 10) Explain how scientific theories are open to investigation and have the capacity to be modified.	

Nature of Science

GLE	9	10
2.2.3 **Evaluating Inconsistent Results**	**Evaluate inconsistent or unexpected results from scientific investigations using scientific explanations. W** ▪ (9, 10) Evaluate similar investigations with inconsistent or unexpected results. ▪ (9, 10) Explain whether sufficient data has been obtained to make an explanation or conclusion (e.g., reference previous and current research; incorporate scientific concepts, principles, and theories). ▪ (9, 10) Explain why results from a single investigation or demonstration are not conclusive about a phenomenon.	

GLE	9	10
2.2.4	**Analyze scientific investigations for validity of method and reliability of results. W** ▪ (9, 10) Describe how the methods of an investigation ensured reliable results. ▪ (9, 10) Explain how to increase the reliability of the results of an investigation (e.g., repeating an investigation exactly the same way increases the reliability of the results). ▪ (9, 10) Describe how the methods of an investigation ensured validity (i.e., validity means that the investigation answered the investigative question with confidence; the manipulated variable caused the change in the responding or dependent variable). ▪ (9, 10) Explain the purpose of the steps of an investigation in terms of the validity of the investigation. ▪ (9, 10) Explain how to improve the validity of an investigation (e.g., control more variables, better measuring techniques, increased sample size, control for sample bias, include experimental control condition when appropriate, include a placebo group when appropriate). ▪ (10) Explain an appropriate type of investigation to ensure reliability and validity for a given investigative question (e.g., descriptive, controlled, correlational, comparative, see Appendix D and Appendix E).	

Component 2.2 Nature of Science: Understand the nature of scientific inquiry.

	GLE	9	10
Nature of Science	2.2.5 Evolution of Scientific Ideas	**Understand how scientific knowledge evolves. W** ▪ (9) Explain how existing ideas were synthesized from a long, rich history of scientific explanations and how technological advancements changed scientific theories. ▪ (9, 10) Explain how scientific inquiry results in new facts, evidence, unexpected findings, ideas, explanations, and revisions to current theories. ▪ (9, 10) Explain how results of scientific inquiry may change our understanding of the systems of the natural and constructed world. ▪ (9, 10) Explain how increased understanding of systems leads to new questions to be investigated. ▪ (9, 10) Explain how new ideas need repeated inquiries before acceptance. ▪ (9, 10) Use new tools to investigate a system to discover new facts about the system that lead to new ideas and questions.	

APPENDIX G

HANDS-ON HORTSCIENCE WORKBOOK

A Problem to Solve:
The Scientific Method

The influence of contextual teaching with the problem solving method on students' knowledge of and attitudes toward horticulture, science, and school.

A Hands-On Hortscience Workbook
by Carrie L. Whitcher
Texas A&M University
PhD Candidate, Horticulture

Fall 2004

Hands-On Hortscience Workbook
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The overall goals of this study are for students to learn the scientific method and how to analyze and interpret research data based on the California Science Content Standards for grades 9-12 (listed in Table 1) and the Draft Agriculture Cluster Foundation Standards presently under review by the CA Agriculture Teachers Association (for information, http://www.calaged.org/NewStandards/Index.htm).

Objectives of this study are for students to meet as many of these content and foundation standards through one of two teaching methods: contextual teaching and learning (CTL) and the problem solving method compared to the traditional subject matter approach. The context of horticulture will limit the number of content standards your students may meet but they may learn as many as 11 of the 14 listed below.

Table 1. The California Science Content Standards for students in grades 9-12.

1a. Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.
1b. Identify and communicate sources of unavoidable experimental error.
1c. Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions.
1d. Formulate explanations by using logic and evidence.
1e. Solve scientific problems by using quadratic equations and simple trigonometric, exponential, and logarithmic functions.
1f. Distinguish between hypothesis and theory and scientific terms.
1g. Recognize the usefulness and limitations of models and theories as scientific representations of reality.
1h. Read and interpret topographic and geologic maps.
1i. Analyze the locations, sequences, or time intervals that are characteristic of natural phenomena (e.g., relative ages of rocks, locations of planets over time, and succession of species in an ecosystem).
1j. Recognize the issues of statistical variability and the need for controlled tests.
1k. Recognize the cumulative nature of scientific evidence.
1l. Analyze situations and solve problems that require combining and applying concepts from more than one area of science.
1m. Investigate a science-based societal issue by researching the literature, analyzing data, and communicating the findings. Examples of issues include irradiation of food, cloning of animals by somatic cell nuclear transfer, choice of energy sources, and land and water use decisions in California.
1n. Know that when an observation does not agree with an accepted scientific theory, the observation is sometimes mistaken or fraudulent (e.g., the Piltdown Man fossil or unidentified flying objects) and that the theory is sometimes wrong (e.g., the Ptolemaic model of the movement of the Sun, Moon, and planets).

The scientific method will include making observations, formatting hypotheses, formulating experiments, and analyzing data. The control group will learn about the scientific method using data from previously completed horticulture experiments. This format will use the subject matter approach and students will participate in lectures, read textbooks and browse websites, discuss experiments and analyze data from those experiments.

The problem solving approach students will have the opportunity to use real horticulture materials including plants, potting soil, fertilizers, and other growing supplies to develop their own experiments and formulate hypotheses. The teacher will refrain from lecturing and will place the responsibility of learning back onto the students.

Both classes will take pretests and post-tests to measure if there is an increase of achievement in learning the scientific method and determine the attitudes students have toward horticulture. Horticulture questions will be asked on the achievement tests to determine baseline knowledge of plant nutrition of both classes.

The problem solving approach and the subject matter approach have been outlined in detail below. The success of this research will depend on how closely the teacher follows the prescribed methodology. Some teaching techniques will lend themselves better to either method, some will work for both. You will select what to use for reference materials during the study lessons as far as textbooks, handouts, and use of the World Wide Web.

Each class will take a paper and pencil pretest before beginning the study and a post-test upon completion of the unit. During the experiment the researcher will determine if a delayed post-test is to be given to the classes after the winter break vacation.

Important note: it would be in the students' best interest for the agriculture instructor to not discuss the study or compare class performance with the participating students. This might elevate student activity that may not otherwise occur or upset students who aren't currently participating in any plant growth activities. There will be sufficient plant materials and greenhouse supplies for both horticulture classes to have greenhouse growth studies; although any information gathered from the control class experiments will not be a part of the final research findings due to the delayed nature of their activities until the end of the semester.

If you are proficient in interpreting p-values and writing null and alternative hypotheses and with the problem solving approach as found in Crunkilton and Krebs (1982) and want to go directly to the class unit outline, proceed to page 10. Otherwise, a brief discussion of these topics and the problem solving and subject matter methods follow.

THE PROBLEM SOLVING APPROACH

There are many variations of problem solving instruction. The purpose of this discussion is to describe the problem solving approach to teaching the scientific method in horticulture science, as it is used in this study. The problem solving approach described in this section closely follows the procedures outlined by Crunkilton and Krebs (1982) and Flowers (1986).

The problem solving approach to teaching the scientific method is a student-centered approach to teaching. The role of the teacher is to motivate the students toward the importance of the problem area, to guide the students in making decisions concerning the specific problems to be studied, and to assist the students in drawing conclusions and making applications of the principles learned. You have five major jobs: (1) organize the problem for the students; (2) figure out how to use your own analysis of the materials to help the students understand the media (textbooks, CD-ROM, DVDs, internet search engine—without imposing your understanding on the students); (3) help the students develop skills necessary to pursue the problem; (4) evaluate each student's work so you can give a grade at the end of the unit; (5) participate in the problem inquiry *yourself*.

While the researcher will assist in developing the problem solving unit, take time during this study to record notes, personal thoughts, ideas, activities, or other factors that will be useful in future problem solving teaching activities. This research will only improve student learning and interest if it is kept fresh with new ideas and activities from a professional like you.

There are five main teaching procedures involved in the problem solving approach. They are listed below and discussed in further detail in this chapter:

1. **Interest Approach**—motivating students so that they want to learn the subject.
2. **Group Objectives**—getting the students to list what they need to learn about the subject.
3. **Problem Areas**—students will take their Group Objectives and turn them into questions and skills needed to be learned to meet those objectives.
4. **Problem Solution**—students will find the answers to the Problem Areas, thus learning the subject material (in this case, the scientific method).
5. **Evaluation and Application**—taking what was learned and determining what it means in relation to other course topics, current events, and future topics of the class. This also includes critically evaluating the experiment, its design and operation, and the results. Did this or will this lead to a better management practice?

Interest Approach

The interest approach indicates the manner in which the teacher is going to introduce the problem area to the class (Crunkilton & Krebs, 1982). A variety of techniques may be used by the teacher to conduct the interest approach, including discussion, field trips, films (DVD, video or CD), models, or demonstrations. The variety of approaches is limited only by the teacher's imagination. The goal of the interest approach is to create a felt need on the part of the students for studying the problem area. This felt need will cause the students to realize they do not know enough about the problem area to be successful, and they need to learn more. The interest approach should stimulate a certain amount of enthusiasm in the class for studying the problem area and should set the stage for the establishment of group objectives.

Crunkilton and Krebs (1982, pp. 17-18) list the following as the primary purposes of the interest approach:

1. To arouse the interest of the students in the unit or problem area.

2. To help the students recognize the problems as their own.

3. To help the teacher obtain a fairly accurate picture of how much the students already know.

4. To develop a common background of information within the class regarding the unit or problem area being discussed.

5. To set the stage for the establishment of student objectives.

The scientific method, investigation, and experimentation are primary components in this research. You can stimulate interest in the subject by asking your students the following question: if we want to grow premium bedding plants for a spring plant sale, what do we need to know and do now? This leads to observation, such as asking what do we already know about bedding plants or have observed from them in previous crops.

Group Objectives

The group objectives, or student objectives, are the reasons for studying the problem area. This section could be included in the interest approach, but most often the group objectives are separate from and immediately follow the interest approach in the unit plan. Regardless of whether the group objectives are a part of the interest approach or a separate part of the lesson, group objectives provide a further motivation for studying the problem area. These objectives may be stated in the form of production goals or other measures of desired performance related to the problem area. **These objectives must be drawn from the students in such a way that they are recognized by the students and the teacher as important goals to be accomplished as a result of studying the problem area** (Newcomb, McCracken, & Warmbrod, 1986).

The bedding plant unit objectives or required class subject standards are addressed in this section of the problem solving unit outline on page 10.

Problem Areas

After the group objectives have been stated by the students, the next step is to formulate the specific problems and/or concerns of students related to the problem area. Problems and concerns are stated in question form and should be closely related to the teaching objectives for the problem area. The problems and concerns provide the basis for organizing the information to be taught in the problem area. In most cases, a problem area will contain from 5 to 10 problems and concerns that address the knowledge, skills, and attitudes that must be obtained by the students before the problems may be resolved.

Students can get into small groups and work on these problems or one student can write down ideas during a class brainstorming session (an important teaching technique). Students should keep their own notebooks during the entire time of this research project.

Problem Solution

Learning of subject matter takes place during the problem solution section of the problem area. During this phase a variety of learning activities may be planned to assist students in solving the problems and concerns identified in the previous step. While you are setting up the learning environment; student success depends on the individual. The teacher cannot engineer an experience for students but can create a situation where learning may occur (Finkel, 2000).

The following steps should be followed in solving problems (Crunkilton & Krebs, 1982):

1. Select a problem from the list of problems and concerns. This step may involve arranging all of the problems and concerns identified in a logical order.

2. Use a "trial discussion" to find out what the students already know about the problem and concern to be studied. This step also serves to clarify the problem so that all students are aware of the specific problem to be solved.

3. The teacher selects appropriate teaching techniques to assist the students in solving the problem. The problem solving approach is not limited in the variety of teaching techniques that may be used in this phase of the problem solution.

4. Students can work independently or in small groups or in any combination deemed necessary by the teacher. This may allow many students access to the WWW, reference books or other non-print media (DVDs, CDs, videotapes, interviews, etc.)

5. The teacher or a student leads the class through a final discussion of the problem in which they draw conclusions. During this step students may develop plans of practice which they will apply to their individual situations concerning the problem area.

6. Another problem area is selected, and the process described in steps 2-5 is repeated.

This is the heart and soul of the problem solving teaching method. Students are responsible for his or her education. They are in control of how much they learn and what they get out of the experience.

For our example, students might design plant growth experiments to determine best management practices. (1) A fertilizer trial comparing various rates of water-soluble fertilizers and (2) a comparison of soilless potting mixes on plant growth rates. These can be done simultaneously during a plant nutrition unit (see page 34 for an example).

Evaluation and Application

The application stage of problem solving instruction occurs when students use the knowledge and skills developed in the classroom and laboratory to determine how those skills will work. The application phase allows the students to practice the new skills they have learned, which increase the retention of the knowledge and skills developed. Application may occur in the classroom, laboratory, through field trips, through FFA activities, or as a part of the student's supervised agricultural experience program (Newcomb, McCracken, & Warmbrod, 1986).

The evaluation stage of problem solving also may occur in a variety of ways. Evaluation of student learning may occur long after the conclusion of the problem area through analysis of SAE records and application of principles learned in the classroom. Paper tests are used to evaluate cognitive outcomes at various levels of the cognitive domain. Regardless of the evaluation techniques used, you will determine what your students have learned and how well they are applying principles learned in the classroom to "real life" situations.

Evaluation of the data will occur through data analysis and graphing on Excel. Students will record weekly data measurements on Excel and create a graph at the termination of the experiment. The instructor will generate a p-value and will help students interpret the experiment results from that p-value. Depending on the numbers of experiments designed, students may test several growth parameters (height, leaf number, flower number) and calculate p-values for each.

Understanding what a p-value means in Experimentation

The p-value is the probability that our results occurred by chance. For example, we have class data for geraniums grown in 3 different potting mixes and we calculate a p-value for final plant height of 0.04. This would be saying that our data results: 1) could occur by chance 4 out of 100 times or 2) we can interpret the p-value as 96 times out of 100 the differences in plant heights occurred due to the treatment (the 3 different potting mixes). A p-value of 0.04 is very low and is under the standard acceptable alpha level (level of chance of making an error of rejecting the null hypothesis when we really shouldn't) of 0.05 set by most scientists!

Our class data of 0.04 shows there is a 1 out of 25 chance of rejecting the null hypothesis (that is, rejecting the idea there is no difference on geranium height between the 3 potting mixes) when we shouldn't. Or another way of saying it is we have 1 chance out of 25 of making a mistake and saying our data was significant (significant means our data occurred other than by chance) when it wasn't. ***Remember that the p-value has to be below the alpha level previously determined prior to running the experiment***. For this research study it should be 0.05.

Developing the Null and Alternative Hypothesis

It is a good idea to get your students into the habit of writing out their null hypothesis (Ho) and the alternative hypothesis (Ha). This is what we are really testing, to see if we can reject the null hypothesis. Remember that cannot prove the alternative hypothesis, only support it. For example:

Ho: There is no difference between tomato varieties and pounds of tomatoes produced.

Ha: There is a difference between tomato variety and pounds of tomatoes produced.

Here is another example:

Ho: Fertilizer type has no effect on number of flowers grown on geraniums.

Ha: Fertilizer type has an effect on number of flowers grown on geraniums.

Students may be confused about having a negative/null hypothesis but need to be reminded that we never "prove" anything in science, just give more data to support current theories. If our data supports the alternative hypothesis, it would sound like this:

"Our data shows there is a difference in pounds of tomatoes produced by tomato variety" or "this data supports earlier research that there is a difference in number of flowers grown on geraniums by type of fertilizer applied". That is all we can say and hope to add to the knowledge base of other scientists and greenhouse growers.

Rejecting the Null Hypothesis and Determining Significance!

We look for our p-value to be less than the alpha (α) of 0.05. If our p-value = .0002 (generated by a computer program such as Excel, SPSS, or JMP IN software), we can see that it is well below 0.05, therefore our data is "significant".

Significance has nothing to do with importance, it simply means that our data results occurred other than by chance (and we are able to show that it was most likely the fertilizer treatment, tomato variety or whatever it is we're testing that created the differences in the data results).

Since we can't "prove" anything with our data, the closest we can get is by having "significant data". **<u>The ultimate goal of scientific research is to show significance in data</u>!**

Numbers of Plants to Use in Experiments

To make graphs and charts your students can use as little as three replicates (plants of one cultivar grown under a single treatment) to provide data to generate the mean for that treatment. Since these three data points will vary quite a bit it is better to use 5 or even 10 replicates/treatment. The Excel examples found on page 21 use 10 plants/treatment.

To have Excel generate a p-value between treatments to determine significance from the data your students will need 10 replicates/treatment. <u>Remember that all plants must be of the same variety when testing potting media, fertilizers, or any other treatment on plants</u>. If your students want to compare several cultivars of geraniums in *one potting media* or with *one type of fertilizer*, that is a good design too. As long as your students are comparing "apples to apples" and not "apples to oranges" and can understand the difference when each is appropriate, their experimental design will be flawless.

Teaching Unit Outlines

Unit Plan for Teaching the Scientific Method with Problem Solving/CTL Activities

This is the Unit Plan for the problem solving/CTL class. Your class may not come up with these items so guide them until they arrive at the Group Objectives, (outline item VB)**.** Note that each section addresses a specific part of the scientific method and should not be eliminated from the class discussion or inquiry.

I. Enterprise: Greenhouse Crop Production

II. Unit: Growing Bedding Plants

III. Problem Areas:

- A. Selecting equipment and supplies **[observation]**
- B. Selecting the crop and potting soil (seed, plugs or cuttings) **[hypothesis]**
- C. Preparing for planting or transplanting **[experimentation/collecting data]**
- D. Caring for and maintaining the crop **[observation/experimentation/collecting data]**
- E. Determine if best management practices (BMP) were used **[analyze data and interpret results]**
- F. Learn how the scientific method works. **[the scientific method]**

IV. Teaching/Learning Objectives (to develop the ability of the students):

- A. To select the proper tools, equipment and supplies for bedding plant production.
- B. To determine the best cultivars of bedding plants for their region and market.
- C. To select the best make of tools, equipment and supplies.
- D. To determine the best source for seed, plugs and supplies.
- E. To determine the costs for producing bedding plants.
- F. To determine how many plants their facility can produce.
- G. To determine the proper environmental growing conditions and if the existing facility provides these conditions.
- H. To determine if the crop is receiving the correct fertilizer application.
- I. To determine if the crop is grown in the best soilless media.
- J. To determine if best management practices were used by data collection and evaluation of a bedding plant crop.
- K. To determine what improvements can be made on future crops.
- L. To learn how to use and apply principles of the scientific method to solve problems.

V. Teaching Procedures:

- A. Interest approach for unit **(leading questions asked by the teacher)**:

1. Ask students to describe how they add color to their yard in the spring.
2. Have any students ever grown bedding plants or other crops?
3. How is greenhouse crop production different than traditional field agriculture crop production?
4. What are the main bedding plants used in our local area?
5. Would you like to grow a crop of bedding plants?
6. What do we need to know, or need to know more about, to grow a crop of bedding plants?
7. Would you like to grow bedding plants as part of your SAE?
8. Develop a list of occupations for which knowledge of bedding plant production is needed.
9. How can we connect growing bedding plants with learning about science and the scientific method?

B. Group Objectives **(the students need to generate these objectives)**:

Students can brainstorm or work in groups to come up with these objectives, then they will "own" their problem!

1. To prepare for employment in a horticultural career.
2. To learn how to schedule a horticultural crop from start to finish.
3. To understand how to order supplies and plant materials.
4. To learn about the scientific method and how it relates to crop production.
5. To determine the optimal growing conditions for the facility in that particular region.
6. To understand how to interpret and apply best management practices for the local region.
7. To learn how to take weekly plant growth data and enter it in a spreadsheet.
8. To learn how to create and interpret data from tables and graphs.
9. To learn how to critically analyze literature from professional horticulture industry trade magazines and journal articles.
10. To interpret statistical inferences made from a greenhouse study.
11. To provide recommendations for future horticultural crops and solve problems based on the bedding plant crop results.
12. To develop interest in the Agriscience Fair Career Development Event in the FFA.

C. Study of the Problem Areas:

1. Problem Area #1: Selecting equipment and supplies **[observation]**
   a. Relate to group objectives for the unit
   b. Problems and concerns:
      i. What equipment and supplies are needed for growing bedding plants?

Questions in Problem Area #1 must be answered before moving on to the next problem area!

ii. Where are the best resources for obtaining equipment and supplies?
iii. What are the best companies for obtaining equipment and supplies?
iv. Should the equipment and supplies be leased and/or borrowed?
v. What have we observed in the past or currently doing that we need to change?
vi. How will learning the scientific method help us with this and other problems?

c. Teaching resources:
i. Class textbook
ii. Internet horticultural websites (universities, companies, etc.)
iii. Agriculture Department resources (DVDs, CDs, reference books)
iv. Professional horticulture industry magazines or journals
v. Field trip to local nurseries

2. Problem Area #2: Selecting the crop and potting soil (seeds, plugs or rooted cuttings) **[hypothesis]**

a. Relate to group objectives for the unit
b. Problems and concerns:
i. What bedding plant crop is most suited for our region? Why?
ii. Where are the best resources for obtaining the seeds or plant material?
iii. Why would this crop be a good pilot crop for our class?
iv. How will the class members take responsibility for the crop?
v. What support will the school provide for this activity?
vi. What will we do with the crop at the conclusion of the activity?
vii. What type of potting soil/soilless media or fertilizer would be best for our crops? How could we test this?

c. Teaching resources:
i. Class textbook
ii. Internet horticultural websites (universities, companies, etc.)
iii. Agriculture Department resources (DVDs, CDs, reference books)
iv. Professional horticulture industry magazines or journals
v. Field trip to local nurseries

3. Problem Area #3: Preparing for planting or transplanting **[experimentation/collecting data]**

a. Relate to group objectives for the unit
b. Problems and concerns:
i. How are our seeds, plugs or rooted cuttings planted? Why?

> Use data sheets from existing lab manuals to guide your students in making their own. See Reed (1993) pg. 80 for an example of a useful data sheet.

ii. What is the care of newly planted or transplanted seeds, plugs or rooted cuttings?
iii. Should we take initial measurements after planting or transplanting? If yes, what measurements should we take and in what units (metric)?
iv. How will the class members take responsibility for weekly plant growth measurements?
v. How will the plant growth measurements be recorded?
vi. What is important to test in our study? Potting mix? Fertilizers?
vii. How can we lower the error rate when setting up an experiment?

c. Teaching resources:
i. Class textbook
ii. Internet horticultural websites (universities, companies, etc.)
iii. Agriculture Department resources (DVDs, CDs, reference books—*General Horticulture Laboratory Manual by D.W. Reed, 1993)*
iv. Professional horticulture industry magazines or journals
v. Field trip to local nurseries
vi. Interview with local growers and researchers
vii. Use of Excel software to develop a data sheet for weekly data collection

4. Problem Area #4: Caring for and maintaining the crop **[observation/ experimentation/collecting data]**

> When the class has set up the experiments you can move on to other related topics and still collect weekly data and enter it in Excel. For help with Excel, go to page 21 for a step-by-step explanation with diagrams.

a. Relate to group objectives for the unit
b. Problems and concerns:
i. What daily activities need to occur with the crop?
ii. How will the crop receive critical growth requirements (ambient temperatures, water, light, fertilizers, etc.)?
iii. Who will record plant growth data and how will it be recorded?
iv. How will we determine if the crop is growing well?
v. How can we determine if we are using the best fertilizer or potting media?

c. Teaching resources:
i. Class textbook
ii. Internet horticultural websites (universities, companies, etc.)
iii. Agriculture Department resources (DVDs, CDs, reference books—*General Horticulture Laboratory Manual*)
iv. Professional horticulture industry magazines or journals
v. Field trip to local nurseries

vi. Interview with local growers and researchers
vii. Use of Excel software to develop a data sheet for weekly data collection

5. Problem Area #5: Determine if best management practices (BMP) were used **[analyze data and interpreting results]**
 a. Relate to group objectives for the unit
 b. Problems and concerns:
  i. Should we have kept a journal (daily, weekly) of the crops' activities?
  ii. How can we compare our different treatments? (Visually with pictures, tables and graphs or statistically with Excel software)
  iii. What can we do with this new information? How will it help us with our next crop?
 c. Teaching resources:
  i. Internet horticultural websites (universities, companies, etc.)
  ii. Agriculture Department resources (DVDs, CDs, reference books)
  iii. Professional horticulture industry magazines or journals
  iv. Interview with local growers and researchers

> Now is the time for students to take their data on Excel and make graphs and run statistical analysis to see if their results were significant. This is what we have all been waiting for!

D. Problem Area #6: Learn how the scientific method works. **[the scientific method]**
 a. Relate the group activities to each of the scientific method principles.
 b. Problems and concerns:
  i. How did each part of the scientific method help us learn?
  ii. Were there parts of the scientific method that were easier or harder to do?
  iii. How can we use the scientific method in our other classes?

VI. Evaluation and Application:
 A. Tests
 B. Have students develop a written plan or PowerPoint presentation for improving bedding plant production
 C. Summarize approved practices
 D. Identify principles of bedding plant production
 E. Create a hortscience poster using CDE Agriscience Fair criteria
 F. Summarize statistical significance of the bedding plant research

VII. Suggested References:
 A. Reed, D.W. 1993. *General horticulture laboratory manual*. 2nd ed. Pearson Custom Publishing, Boston, MA.

B. *Ball RedBook*, 17th edition, vols. 1 & 2, Ball Publishing, Batavia, IL.
C. Reiley, H.E. and C.L. Shry, Jr. 2002. *Introductory horticulture*, 6th ed. Delmar Thomson Learning, Albany, NY.
D. Crunkilton, J. R., & Krebs, A. H. 1982. *Teaching agriculture through problem solving* 3rd ed. Danville: Interstate Printers & Publishers, Inc.
E. Finkel, D. L. 2000. *Teaching with your mouth shut*. Portsmouth: Boynton/Cook Publishers, Inc.
F. Newcomb, L. H., McCracken, J. D., & Warmbrod, J. R. (1993). *Methods of teaching agriculture*. Danville, IL: Interstate Publishers, Inc.
G. Flowers, J. L. 1986. Effects of the problem solving approach on achievement, retention, and attitudes. University of Illinois, Urbana.

THE SUBJECT MATTER (LECTURE) APPROACH

The subject matter approach is a popular teaching method used by agriculture teachers. This discussion will describe this approach to teaching the scientific method, as it is used in this study.

The subject matter approach to teaching the scientific method is a teacher-centered approach to teaching that uses a specific subject matter as the context. It usually involves a lot of lecturing on the behalf of the teacher. Using this approach, the teacher selects the subject matter to be studied, explains the importance of studying the topic to the students, and selects the learning activities to teach the subject matter. Each of the major steps involved in the subject matter approach is described below.

Introduction

The purpose of the introduction to the problem area is to explain the importance of studying the subject matter to the students. A variety of techniques may be used during the introduction to stimulate student interest in the topic, but discussion is the most common technique used. The primary purpose of the introduction is to set the stage for the presentation of information while utilizing a context associated with the scope of the course.

For our control class, we can have the students look over class data from previous bedding plant experiments (look at page 21 for this data) and have them pull out their observations from these results. They can add to their observations by using the WWW and researching what is known about bedding plant production.

Presentation of Subject Matter

The subject matter to be taught to students is organized around specific learning objectives developed by the teacher. These learning objectives, or teacher objectives, are not usually shared with the students. During this step in the subject matter approach, the teacher selects appropriate teaching techniques to accomplish the desired learning objectives. The teacher may select from a variety of teaching techniques, including lecture, supervised study, field trips, demonstrations, films (videos, DVDs, CDs), etc. Regardless of the technique selected, the teacher leads the activity selected to accomplish the objectives of the lesson.

Students can develop their hypotheses from independent study or from group work. This can be from assigned reading, lecture notes, or handouts presented by the teacher.

Review

The purpose of the review step in the subject matter approach is to draw closure to the discussion and to emphasize important points in the lesson. Review may also be used to draw conclusions, although this step is usually not included. Due to the nature of the teacher's presentations, students often are not asked to draw conclusions. Instead the subject matter is presented by the teacher as facts which the students are asked to commit to memory.

Evaluation

The evaluation phase of the subject matter approach involves determining what the students have learned as a result of the instruction. Paper and pencil tests are used to evaluate cognitive outcomes at various levels. Evaluation could also include a determination of whether the knowledge and skills learned in the classroom have been applied by the students.

Teaching Unit Outlines

Unit Plan for Teaching the Scientific Method with Subject Matter Teaching Activities

This is the Unit Plan for the control class. You will have the Group Objectives (outline item VB from page 11) already in your regular teaching plan**.** This unit plan is somewhat similar to the problem solving plan in that each section addresses a specific part of the scientific method and should not be eliminated from the class discussion or lecture presentation.

It is up to the instructor to teach how the scientific method works and where it would fit into this unit on bedding plants. Worksheets, videos, lecture, and reading assignment all fit here.

Unit Plan

I. Enterprise: Greenhouse Crop Production

II. Unit: Growing Bedding Plants

III. Problem Areas:

- A. Selecting equipment and supplies **[observation]**
- B. Selecting the crop (seed, plugs or cuttings) **[hypothesis]**
- C. Preparing for planting or transplanting **[experimentation/collecting data]**
- D. Caring for and maintaining the crop **[experimentation/collecting data]**
- E. Determine if best management practices (BMP) were used from previous experimental data **[analyze data and interpret results]**
- F. Learn how the scientific method works. **[the scientific method]**

IV. Teaching/Learning Objectives (to develop the ability of the students):

- A. To select the proper tools, equipment and supplies for bedding plant production.
- B. To select the best make of tools, equipment and supplies.
- C. To determine the best resources for seed, plugs and supplies.
- D. To determine how many plants their facility can produce.
- E. To determine the proper environmental growing conditions and if the existing facility provides these conditions.
- F. To determine if the crop is receiving the correct fertilizer application.
- G. To determine if the crop is grown in the best soilless media.
- H. To determine if best management practices were used.
- I. To use the scientific method to determine the aforementioned objectives.
- J. To learn how to use and apply principles of the scientific method to solve problems.

V. Suggested References: (other available references may be used):
   A. (CLF6000) Advanced Core Cluster: Ornamental Horticulture
      1. (CLF6600) Unit Title: Growth and Maintenance of Nursery Stock
         a. (CLF6603) Mixing Growing Media
      2. (CLF6400) Unit Title: Horticultural Soils & Planting Media
         a. (CLF6401) Soil Basics
         b. (CLF6402) Horticultural Soils
      3. (CLF6350) Unit Title: Elements Necessary for Plant Growth
      4. (CLF6500) Unit Title: Selection, Planting and Care of Ornamental Plants

Helpful Websites for Student Research

Potting Soils (Soilless Media) and Fertilizers

http://hgic.clemson.edu/factsheets/HGIC1456.htm
http://www.hummert.com/
http://www.kellogggarden.com/index.html
http://www.miraclegro.com/
http://www.premierhort.com/website/afhome.html
http://www.sungro.com/

Plants, Seeds, Rooted Cuttings

http://www.ballfloraplant.com/BFP/bfp_search.jsp
http://www.ecke.com/Search/Variety_Search.asp
http://www.provenwinners.com/main.cfm
http://www.speedling.com/
http://www.theflowerfields.com/ffa/grower.aspx
http://yoder.com/

The Scientific Method

http://phyun5.ucr.edu/~wudka/Physics7/Notes_www/node5.htm
http://school.discovery.com/sciencefaircentral/scifairstudio/handbook/scientificmethod.html
http://teacher.nsrl.rochester.edu/phy_labs/AppendixE/AppendixE.html

Experimental Error

http://instruct1.cit.cornell.edu/courses/virtual_lab/LabZero/Experimental_Error.shtml
http://www.carlton.paschools.pa.sk.ca/chemical/Sigfigs/experimental_errors.htm
http://www.nyu.edu/classes/sundheim/Stat/Stat.htm

Examples to Demonstrate the CA Science Content Standards to Students (*each standard is listed, followed by examples*):

1a. *Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.*

Students can design their own data sheets on Excel using models provided by the teacher or those found on the WWW. Later on the instructor will show them how to use Excel to add, subtract, etc. and perform statistical analysis and interpreting p-values from data.

1b. *Identify and communicate sources of unavoidable experimental error.*
1c. *Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions.*

A third of the class can measure the length of a pencil, another third can measure the length of a soda can and the remainder can measure the diameter of a paper plate. Have the students take the average (the mean) of their measurements.
--What is error? Error is the deviation of measurements from the mean.
--Did your students have high or low measurement error for any of the items?
--How will this affect how we take measurements on the plants throughout the experiment?

It is important to stress consistency throughout the entire experiment for credible results. Have students get to know how to measure accurately and precisely with a metric ruler at the beginning of the experiment so they have good work habits throughout the project.

1d. *Formulate explanations by using logic and evidence.*
1j. *Recognize the issues of statistical variability and the need for controlled tests.*

Use the statistical analysis in conjunction with the visual observations and data to explain the results of the experiment. Have the students look at their graphical data, the recorded data, and any p-values generated to determine how the results came to be.
--Were there any plants that died?
--Were the conditions in the greenhouse ideal and/or consistent throughout the entire crop time?
--This would be where the need for control plants would be discussed.

1e. *Solve scientific problems by using quadratic equations and simple trigonometric, exponential, and logarithmic functions.*

The data will most likely be linear or a bell-shaped curve so no transformation of the data in this standard will be necessary.

1f. *Distinguish between hypothesis and theory and scientific terms.*

1g. *Recognize the usefulness and limitations of models and theories as scientific representations of reality.*

During the class brainstorming sessions these can be defined and discussed by the group.

1h. *Read and interpret topographic and geologic maps.*

Since this is a greenhouse experiment, geologic maps probably aren't necessary but for those at high altitudes encountering various climate changes, this could be a topic of interest.

1i. *Analyze the locations, sequences, or time intervals that are characteristic of natural phenomena (e.g., relative ages of rocks, locations of planets over time, and succession of species in an ecosystem).*

Current plant cultivars arrived through modern selection and breeding practices, an enhanced succession of the species. This would make for interesting class discussion.

1k. *Recognize the cumulative nature of scientific evidence.*

1l. *Analyze situations and solve problems that require combining and applying concepts from more than one area of science.*

In the beginning of this class unit when students are discussing observations, previous work could be exhibited by students to explain the need for this work and experimentation. Students could also tie in other topics they are learning in their other classes to this study.

1m. *Investigate a science-based societal issue by researching the literature, analyzing data, and communicating the findings. Examples of issues include irradiation of food, cloning of animals by somatic cell nuclear transfer, choice of energy sources, and land and water use decisions in California.*

This research provides a perfect opportunity to hold discussion on water use decisions in CA and WA, the use of water-soluble fertilizers and ground water runoff, etc.

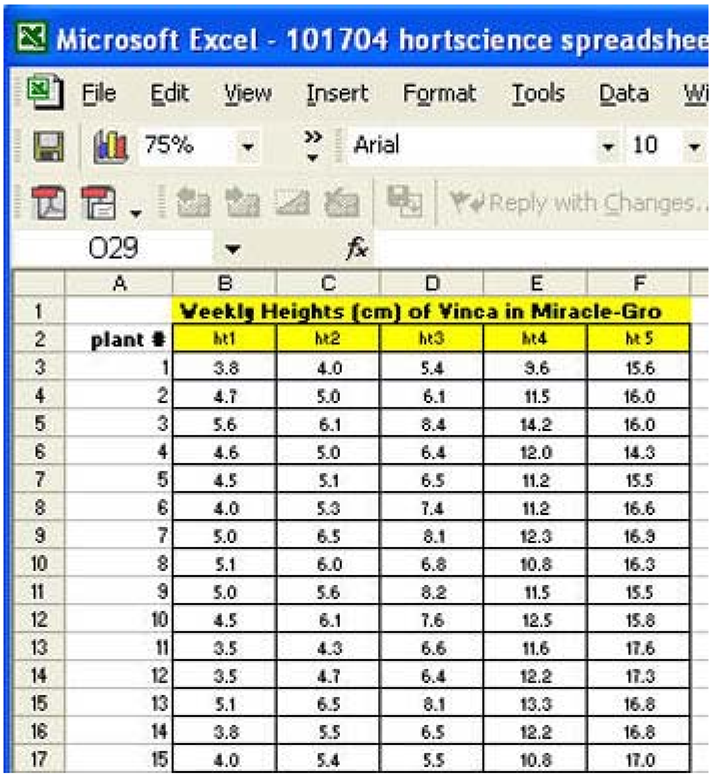
1n. *Know that when an observation does not agree with an accepted scientific theory, the observation is sometimes mistaken or fraudulent (e.g., the Piltdown Man fossil or unidentified flying objects) and that the theory is sometimes wrong (e.g., the Ptolemaic model of the movement of the Sun, Moon, and planets).*

Have students know the difference between accuracy and precision when they are taking their measurements to avoid mistaken observations. Students can also discuss how fertilizers are taken up into plant roots as inorganic minerals. No matter what the original fertilizer was (either organic or inorganic), all fertilizers must be broken down into inorganic elements or molecules.

Making a Datasheet with Excel

For teachers and students unfamiliar with Excel, Excel is simply a spreadsheet program that has the capability of various mathematical and statistical functions with amazing ability to organize data by using rows and columns (see Figure 1 below):

Figure 1. Weekly heights (cm) of Vinca 'Pacifica Red' grown in Miracle-Gro™ media*.



	A	B	C	D	E	F
1		Weekly Heights (cm) of Vinca in Miracle-Gro				
2	plant #	ht1	ht2	ht3	ht4	ht 5
3	1	3.8	4.0	5.4	9.6	15.6
4	2	4.7	5.0	6.1	11.5	16.0
5	3	5.6	6.1	8.4	14.2	16.0
6	4	4.6	5.0	6.4	12.0	14.3
7	5	4.5	5.1	6.5	11.2	15.5
8	6	4.0	5.3	7.4	11.2	16.6
9	7	5.0	6.5	8.1	12.3	16.9
10	8	5.1	6.0	6.8	10.8	16.3
11	9	5.0	5.6	8.2	11.5	15.5
12	10	4.5	6.1	7.6	12.5	15.8
13	11	3.5	4.3	6.6	11.6	17.6
14	12	3.5	4.7	6.4	12.2	17.3
15	13	5.1	6.5	8.1	13.3	16.8
16	14	3.8	5.5	6.5	12.2	16.8
17	15	4.0	5.4	5.5	10.8	17.0

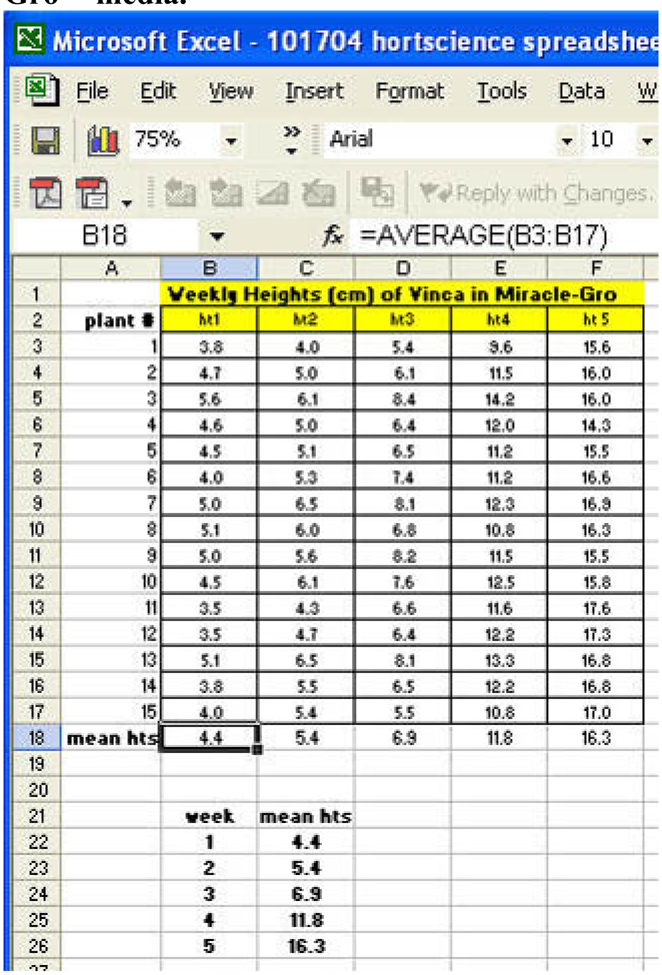
Each week students can measure the heights of their test plants in centimeters (in this example there are 15 plants potted in one soilless mix in 10 cm [4"] pots) and enter them in columns by week on Excel. (**Use of trademarked materials does not imply endorsement for such products*).

Students can enter heights, weights, leaf numbers, etc. for any growth parameter they choose. Be sure to go over both random and systematic error with measurements. Random error is caused by inaccurate measurements or carelessness and can lower the chance of showing significant results in the data.

Systematic error comes from having a piece of equipment not work correctly or something that affects the treatments throughout the duration of the experiment, (e.g., a scale that is off by 5 grams, the heater in the greenhouse blows on one side of a bench more than another side) causing skewed results. Both random error and systematic error can be lessened with careful planning and attention to detail.

Your students may use something similar to this or may copy a data sheet from an existing lab exercise or can develop their own! Encourage them to be creative with their data sheets.
Data from each plant (better known as a replication) can be graphed over time to see how certain plants are growing. Also, data from each week can be averaged at the bottom of each column and compared to other week's mean heights in a graph (Figure 2).

Figure 2. Mean weekly heights (cm) of Vinca 'Pacifica Red' grown in Miracle-Gro™ media.



	A	B	C	D	E	F
1		Weekly Heights (cm) of Vinca in Miracle-Gro				
2	plant #	ht1	ht2	ht3	ht4	ht 5
3	1	3.8	4.0	5.4	9.6	15.6
4	2	4.7	5.0	6.1	11.5	16.0
5	3	5.6	6.1	8.4	14.2	16.0
6	4	4.6	5.0	6.4	12.0	14.3
7	5	4.5	5.1	6.5	11.2	15.5
8	6	4.0	5.3	7.4	11.2	16.6
9	7	5.0	6.5	8.1	12.3	16.9
10	8	5.1	6.0	6.8	10.8	16.3
11	9	5.0	5.6	8.2	11.5	15.5
12	10	4.5	6.1	7.6	12.5	15.8
13	11	3.5	4.3	6.6	11.6	17.6
14	12	3.5	4.7	6.4	12.2	17.3
15	13	5.1	6.5	8.1	13.3	16.8
16	14	3.8	5.5	6.5	12.2	16.8
17	15	4.0	5.4	5.5	10.8	17.0
18	mean hts	4.4	5.4	6.9	11.8	16.3

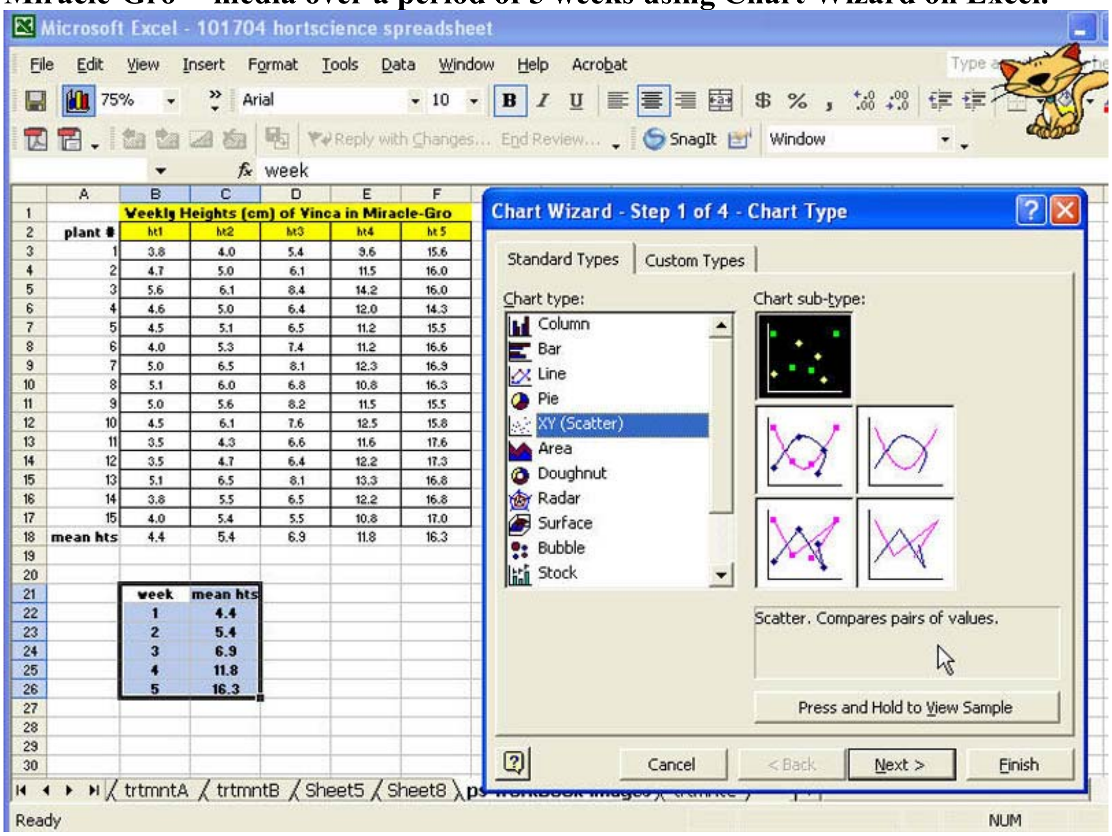
	B	C
21	week	mean hts
22	1	4.4
23	2	5.4
24	3	6.9
25	4	11.8
26	5	16.3

The function to compute the mean can be found on the formula bar on Excel in Figure 2 (to find the mean of a set of values, click on the *f*x button and click on average). After this is done, mean heights can be copied and pasted (paste special, paste values, transpose) into a column (those in Figure 2 were changed to one decimal point by highlighting them, clicking on format, cells, number, and then ok).

Graphing Data on Excel

What if your students want to see their weekly data in a graph form? Easy! As in Figure 3, highlight the week and mean heights columns, click on the Chart Wizard button (Figure 4 if you can't find it on your screen), scroll down and click on XY Scatter and Next, Next again, enter your graph's title, X axis and Y axis (include measurement units), and Finish. The graph will appear in the middle of the screen and can be saved as an image for putting into research papers, PowerPoint presentations, etc.

Figure 3. Graphing the mean weekly heights (cm) of Vinca 'Pacifica Red' grown in Miracle-Gro™ media over a period of 5 weeks using Chart Wizard on Excel.



The Chart Wizard saves you time as it guides you through the graph-creating steps (see Figures 5 and 6 for Chart Wizard steps to making titles and labeling the X and Y axes).

Figure 4. Graphing with Chart Wizard on Excel begins by clicking on the button.

Figure 5. Step 2 of graphing the mean weekly heights (cm) of Vinca 'Pacifica Red' grown in Miracle-Gro™ media over a period of 5 weeks using Chart Wizard on Excel.

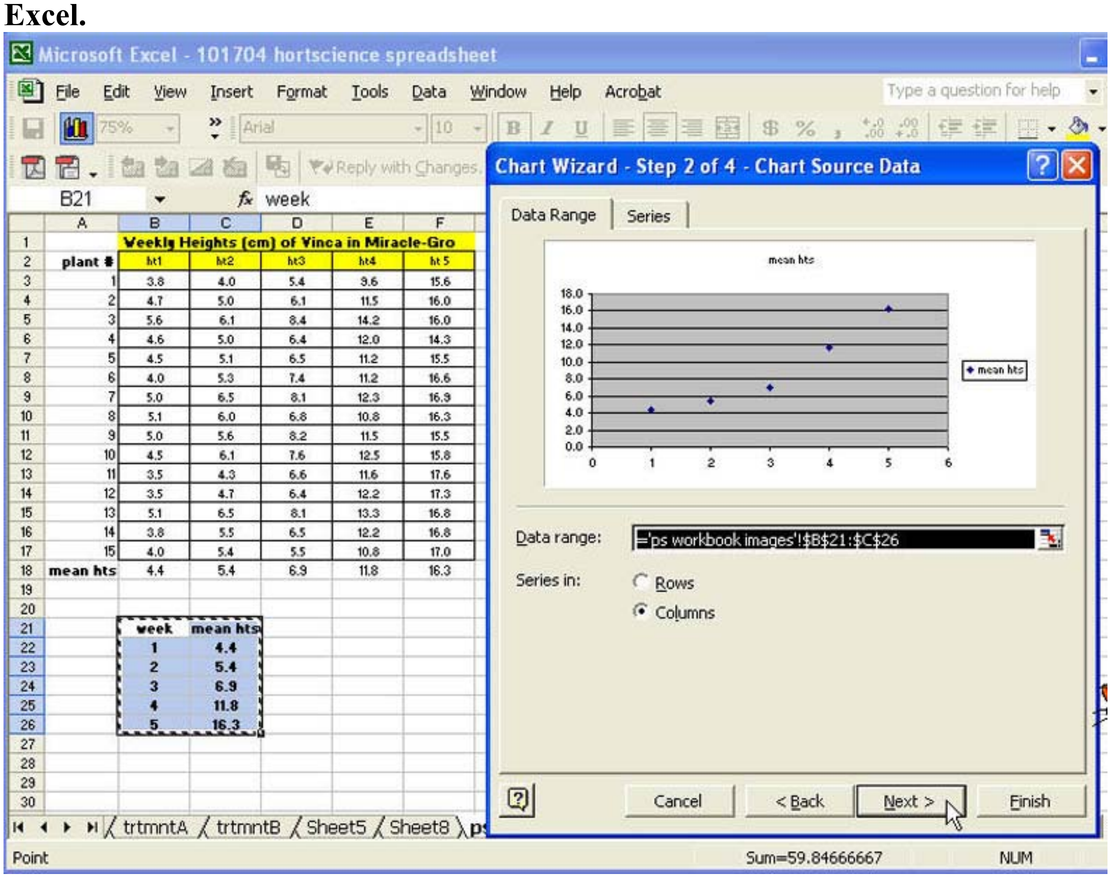
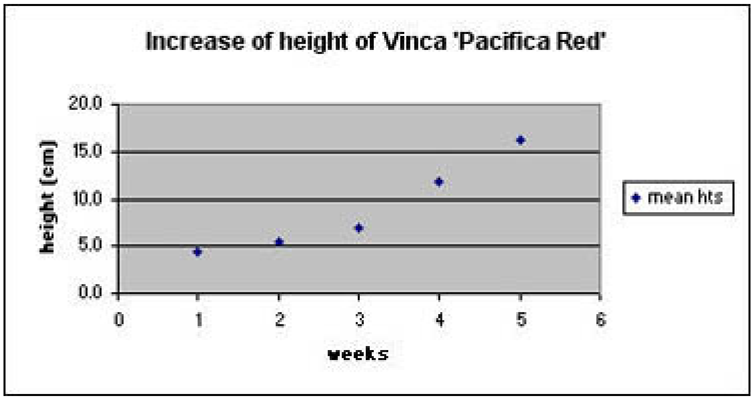
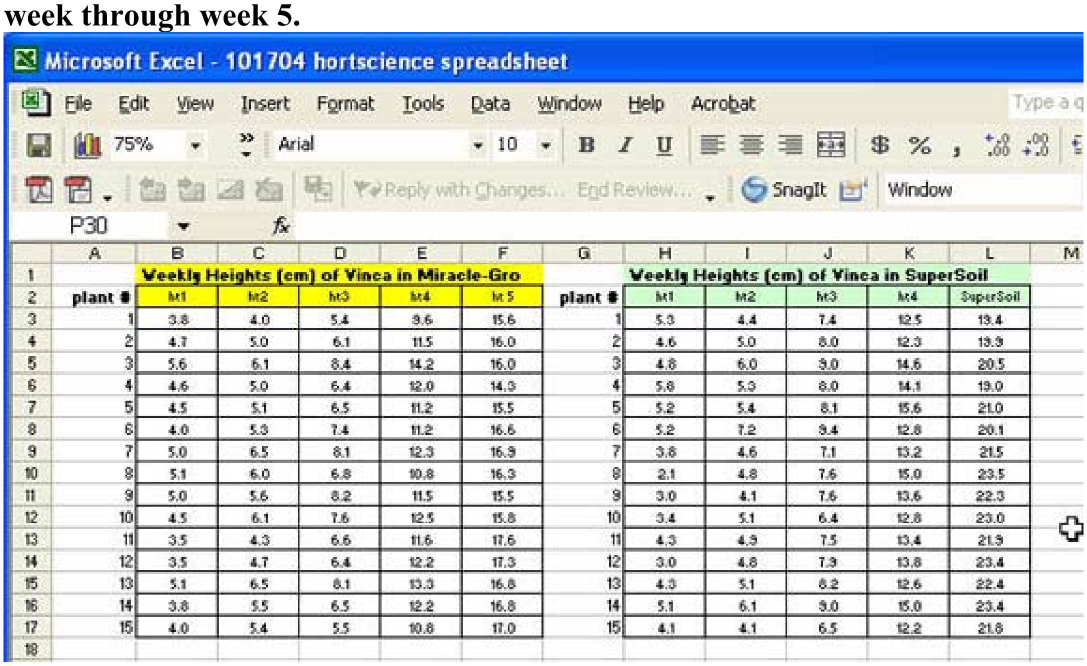


Figure 6. The completed graph of the mean weekly heights (cm) of Vinca 'Pacifica Red' grown in Miracle-Gro™ media over a period of 5 weeks using Chart Wizard.



If your students are testing the effects of two different media, such as SuperSoil™ and Miracle-Gro™, they could have two separate charts with the weekly height measurements recorded in each column (Figure 7). Keeping the data separate for plants grown in each potting mix will be easier to manage by highlighting the top of each chart in different colors.

Figure 7. Mean weekly heights (cm) of Vinca 'Pacifica Red' grown in Miracle-Gro™ media (yellow) and SuperSoil™ media (green). Row 2 is labeled for each week through week 5.



	A	B	C	D	E	F	G	H	I	J	K	L	M
1		Weekly Heights (cm) of Vinca in Miracle-Gro						Weekly Heights (cm) of Vinca in SuperSoil					
2	plant #	ht1	ht2	ht3	ht4	ht 5	plant #	ht1	ht2	ht3	ht4	SuperSoil	
3	1	3.8	4.0	5.4	9.6	15.6	1	5.3	4.4	7.4	12.5	13.4	
4	2	4.7	5.0	6.1	11.5	16.0	2	4.6	5.0	8.0	12.3	13.9	
5	3	5.6	6.1	8.4	14.2	16.0	3	4.8	6.0	9.0	14.6	20.5	
6	4	4.6	5.0	6.4	12.0	14.3	4	5.8	5.3	8.0	14.1	19.0	
7	5	4.5	5.1	6.5	11.2	15.5	5	5.2	5.4	8.1	15.6	21.0	
8	6	4.0	5.3	7.4	11.2	16.6	6	5.2	7.2	9.4	12.8	20.1	
9	7	5.0	6.5	8.1	12.3	16.9	7	3.8	4.6	7.1	13.2	21.5	
10	8	5.1	6.0	6.8	10.8	16.3	8	2.1	4.8	7.6	15.0	23.5	
11	9	5.0	5.6	8.2	11.5	15.5	9	3.0	4.1	7.6	13.6	22.3	
12	10	4.5	6.1	7.6	12.5	15.8	10	3.4	5.1	6.4	12.8	23.0	
13	11	3.5	4.3	6.6	11.6	17.6	11	4.3	4.9	7.5	13.4	21.9	
14	12	3.5	4.7	6.4	12.2	17.3	12	3.0	4.8	7.9	13.8	23.4	
15	13	5.1	6.5	8.1	13.3	16.8	13	4.3	5.1	8.2	12.6	22.4	
16	14	3.8	5.5	6.5	12.2	16.8	14	5.1	6.1	9.0	15.0	23.4	
17	15	4.0	5.4	5.5	10.8	17.0	15	4.1	4.1	6.5	12.2	21.8	
18													

Comparing Means Between Plants Grown in Two Different Potting Mixes
By having two similar charts side-by-side, students can easily track and enter weekly data. Comparing final height data between the 15 plants grown in each potting mix can also be done graphically and statistically in Excel. Here is how to make a graph first (Figure 8). First highlight the plant numbers and hold down the control button while highlighting the other column you wish to compare graphically (you can copy and paste similar columns so they are side-by-side, such as the final week height column, to make highlighting easier). The Chart Wizard will take you through the same steps as seen previously and is shown again with this data in Figure 9.

Figure 8. Comparing the mean weekly heights (cm) of Vinca ‘Pacifica Red’ grown in Miracle-Gro™ media (yellow) and SuperSoil™ media (green).

G	H	I	J	K	L	M
	Weekly Heights (cm) of Vinca in SuperSoil					
plant #	ht1	ht2	ht3	ht4	SuperSoil	Miracle-Gro
1	5.3	4.4	7.4	12.5	19.4	15.6
2	4.6	5.0	8.0	12.3	19.9	16.0
3	4.8	6.0	9.0	14.6	20.5	16.0
4	5.8	5.3	8.0	14.1	19.0	14.3
5	5.2	5.4	8.1	15.6	21.0	15.5
6	5.2	7.2	9.4	12.8	20.1	16.6
7	3.8	4.6	7.1	13.2	21.5	16.9
8	2.1	4.8	7.6	15.0	23.5	16.3
9	3.0	4.1	7.6	13.6	22.3	15.5
10	3.4	5.1	6.4	12.8	23.0	15.8
11	4.3	4.9	7.5	13.4	21.9	17.6
12	3.0	4.8	7.9	13.8	23.4	17.3
13	4.3	5.1	8.2	12.6	22.4	16.8
14	5.1	6.1	9.0	15.0	23.4	16.8
15	4.1	4.1	6.5	12.2	21.8	17.0

Click on the Chart Wizard button to bring up the XY (Scatter) graph. Follow through the steps adding titles and axis labels until you are finished. If you include the titles of each potting mix from Row 1 the Chart Wizard makes a complete legend for you with those potting mix titles (Figure 10).

Figure 9. Graphing the mean weekly heights (cm) of Vinca 'Pacifica Red' grown in Miracle-Gro™ media (yellow) and SuperSoil™ media (green) with Chart Wizard.

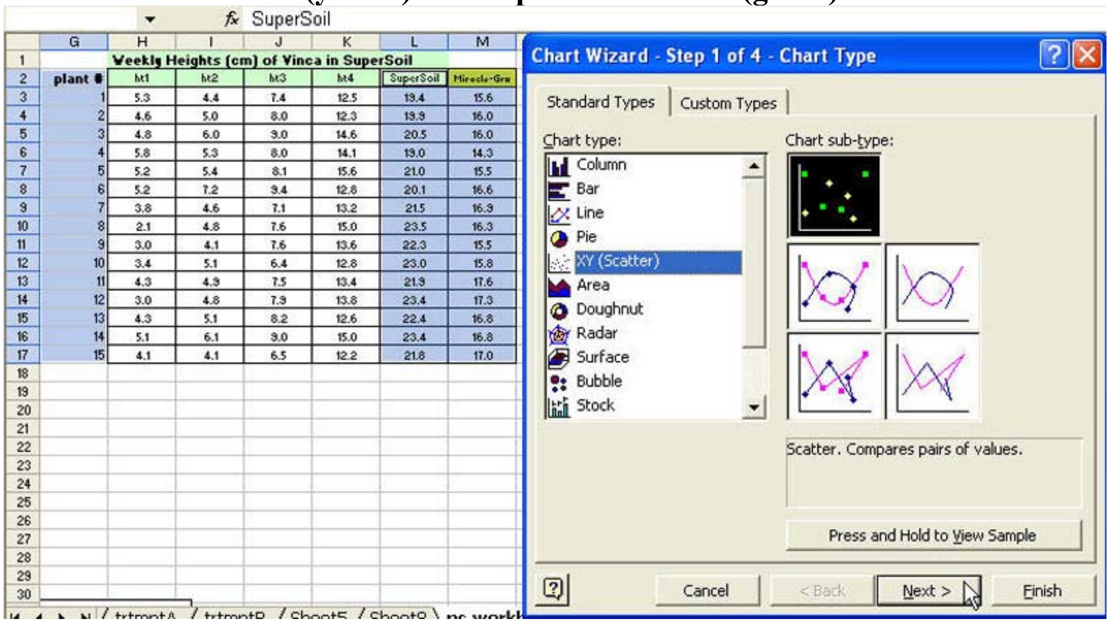
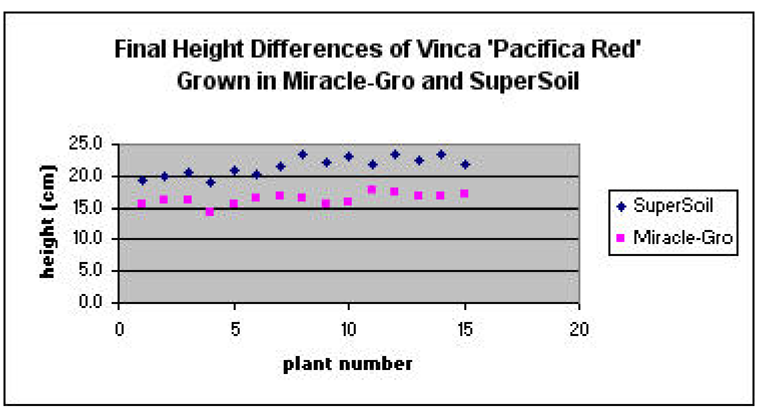
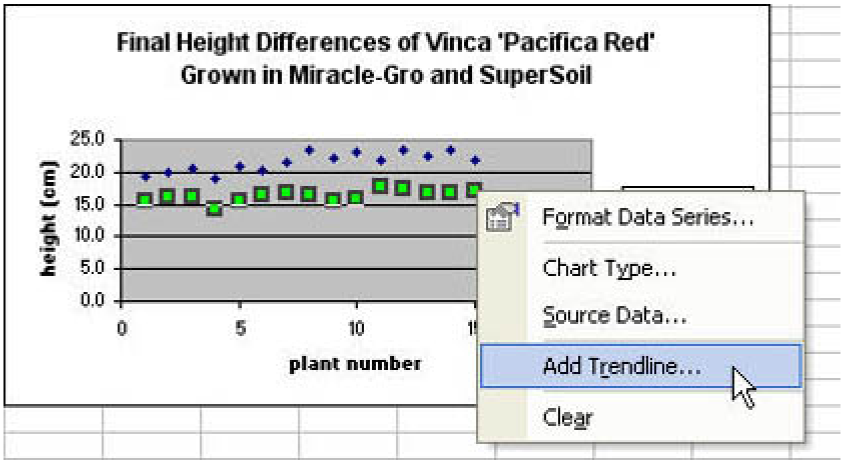


Figure 10. The finished graph of the final weekly heights (cm) of Vinca 'Pacifica Red' grown in Miracle-Gro™ and SuperSoil™ media. Note the potting mix names in the legend.



What is great about Excel is the ability to insert a trendline in the data on a graph and see what the data are doing in a linear way. This helps separate treatments in a more visual manner. Clicking on any of the data points brings up a menu that includes Add Trendline (Figures 11 and 12). The trendline represents the mean of your students' data points.

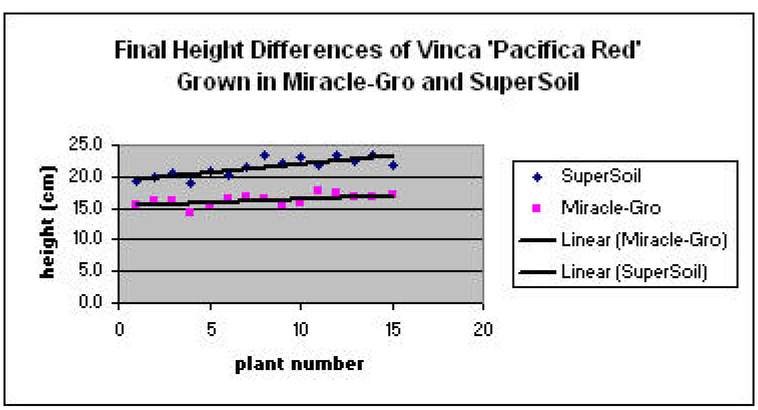
Figure 11. Adding a trendline to the mean data points from the weekly heights (cm) of Vinca 'Pacifica Red' grown in Miracle-Gro™ and SuperSoil™ media.



Trendlines are helpful to quickly see what the data points are doing, whether growth is occurring fast or slow and on which treatments. Drastic or extreme data points can be noted: were these entered incorrectly into Excel or is there a problem with the plants where this data originated?

From Figure 12 below, it appears that the SuperSoil treatment is giving better growth results than the Miracle-Gro treatment. What were some of the SuperSoil ingredients that may have boosted vinca growth? That is a good question for students to follow up.

Figure 12. Adding a trendline to both sets of mean data points from the weekly heights (cm) of Vinca 'Pacifica Red' grown in Miracle-Gro™ and SuperSoil™ media.



Determining Statistical Differences Between Data Points

Now that we can see differences graphically, can we show statistically that one treatment is different (growing better or worse) than the other? By using the Data Analysis plug-in that comes with Excel, we can run simple statistical analysis of our final height data between both soilless media types (the Miracle-Gro™ and SuperSoil™ media).

Going to our data charts on Excel (Figures 13 and 14, on the next page), go to the menus for Tools, Data Analysis, ANOVA Single Factor, click on ok. The Input Range can be filled in by highlighting both final height columns with the mouse, and click on ok. If you include the titles be sure to check the Labels in the First Row box (Figure 15). Click ok and the statistical analysis will run for you and will have an output on a new worksheet.

Figure 13. Determining statistical differences in Vinca 'Pacifica Red' final height (cm) grown in Miracle-Gro™ and SuperSoil™ media with the Data Analysis feature.

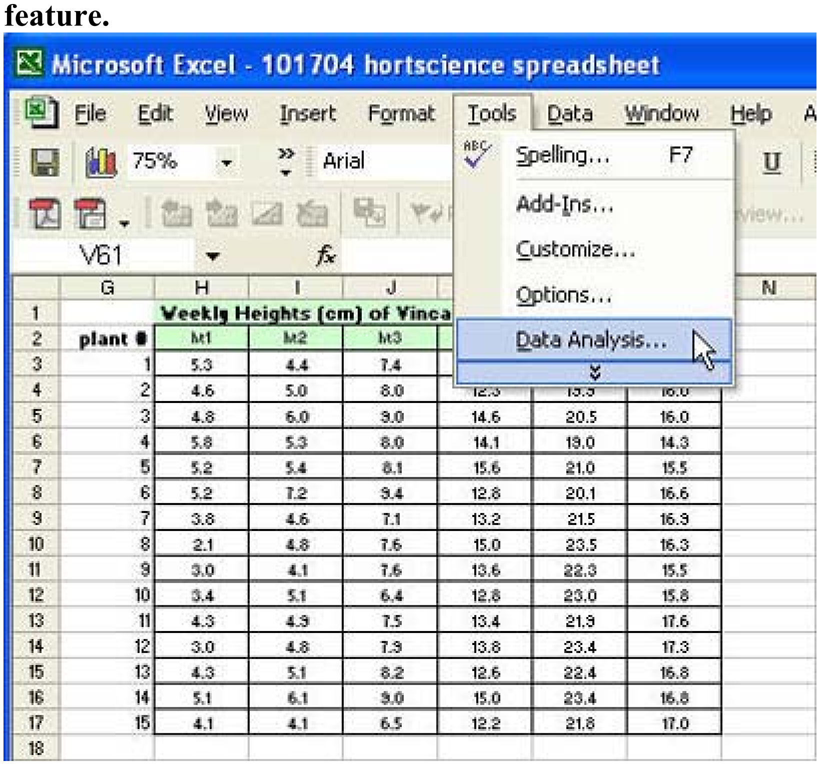


Figure 14. Determining statistical differences in Vinca 'Pacifica Red' final height (cm) grown in Miracle-Gro™ and SuperSoil™ media by highlighting both columns of data.

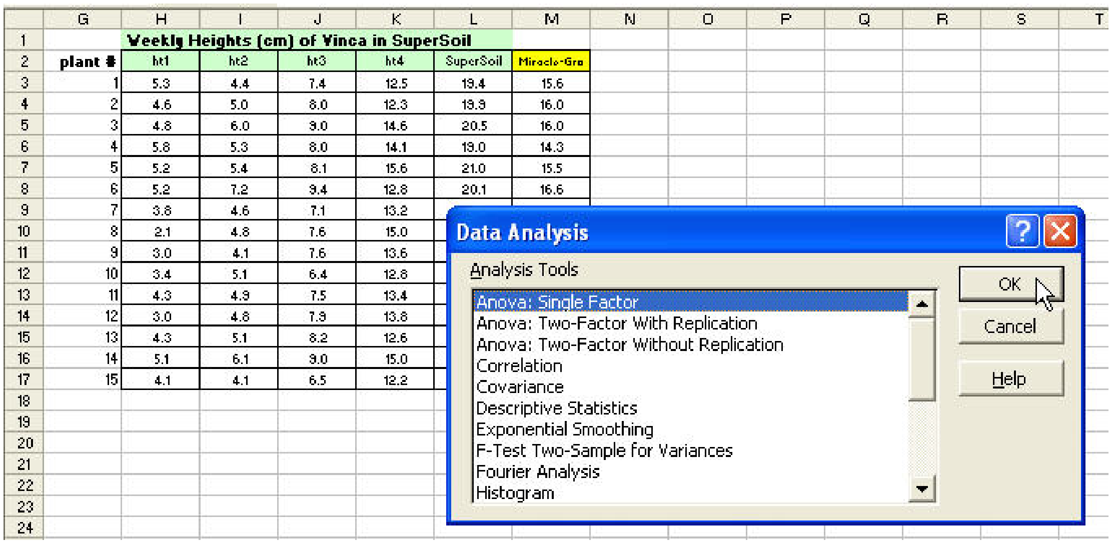
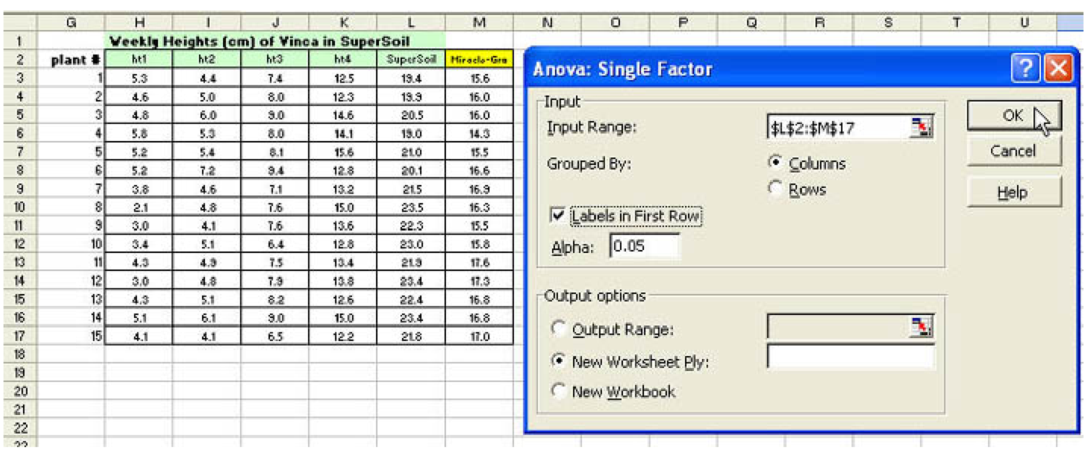


Figure 15. Determining statistical differences with ANOVA in Vinca 'Pacifica Red' final height (cm) grown in Miracle-Gro™ and SuperSoil™ media.



After clicking ok, the ANOVA Single Factor Summary table and ANOVA table will appear on a new worksheet (Figure 16). As mentioned in the Evaluation and Application section on page 7, the lower the p-value, the lesser chance that our data results were due to random chance (and not by treatment). As Figure 16 shows in the ANOVA table, the p-value of 2.18 $x10^{-12}$ is extremely smaller than our alpha of 0.05. This is the probability our data came about by random chance, which seems highly unlikely! It looks like the

SuperSoil™ outperformed the Miracle-Gro™ by having taller plants and we have significance in our results to back our research study up.

Figure 16. Determining statistical differences with p-values in the ANOVA table in Vinca 'Pacifica Red' final height (cm) grown in Miracle-Gro™ compared to SuperSoil™ media.

	A	B	C	D	E	F	G
1	Anova: Single Factor						
2							
3	SUMMARY						
4	*Groups*	*Count*	*Sum*	*Average*	*Variance*		
5	SuperSoil	15	323.1	21.54	2.255429		
6	Miracle-Gro	15	244	16.26667	0.736667		
7							
8							
9	ANOVA						
10	*Source of Variation*	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
11	Between Groups	208.5603	1	208.5603	139.4076	2.18E-12	4.195982
12	Within Groups	41.88933	28	1.496048			
13							
14	Total	250.4497	29				
15							

Plant Growth Data for Subject Matter Control Group

The following data can be used with the subject matter control group to demonstrate how data can be collected, analyzed and interpreted with Excel. You can either have the students look at the data and graphs or have them enter the data in Excel and make the graphs themselves.

This data is the same data tables and graphs used in the previous section that was for the problem solving group so if you want to walk your students through those steps you already know how!

	Weekly Heights (cm) of Vinca in Miracle-Gro				
plant #	ht1	ht2	ht3	ht4	ht 5
1	3.8	4.0	5.4	9.6	15.6
2	4.7	5.0	6.1	11.5	16.0
3	5.6	6.1	8.4	14.2	16.0
4	4.6	5.0	6.4	12.0	14.3
5	4.5	5.1	6.5	11.2	15.5
6	4.0	5.3	7.4	11.2	16.6
7	5.0	6.5	8.1	12.3	16.9
8	5.1	6.0	6.8	10.8	16.3
9	5.0	5.6	8.2	11.5	15.5
10	4.5	6.1	7.6	12.5	15.8
11	3.5	4.3	6.6	11.6	17.6
12	3.5	4.7	6.4	12.2	17.3
13	5.1	6.5	8.1	13.3	16.8
14	3.8	5.5	6.5	12.2	16.8
15	4.0	5.4	5.5	10.8	17.0

plant #	ht1	ht2	ht3	ht4	SuperSoil
	Weekly Heights (cm) of Vinca in SuperSoil				
1	5.3	4.4	7.4	12.5	19.4
2	4.6	5.0	8.0	12.3	19.9
3	4.8	6.0	9.0	14.6	20.5
4	5.8	5.3	8.0	14.1	19.0
5	5.2	5.4	8.1	15.6	21.0
6	5.2	7.2	9.4	12.8	20.1
7	3.8	4.6	7.1	13.2	21.5
8	2.1	4.8	7.6	15.0	23.5
9	3.0	4.1	7.6	13.6	22.3
10	3.4	5.1	6.4	12.8	23.0
11	4.3	4.9	7.5	13.4	21.9
12	3.0	4.8	7.9	13.8	23.4
13	4.3	5.1	8.2	12.6	22.4
14	5.1	6.1	9.0	15.0	23.4
15	4.1	4.1	6.5	12.2	21.8

Weekly Heights (cm) of Vinca in Miracle-Gro

plant #	ht1	ht2	ht3	ht4	ht 5
1	3.8	4.0	5.4	9.6	15.6
2	4.7	5.0	6.1	11.5	16.0
3	5.6	6.1	8.4	14.2	16.0
4	4.6	5.0	6.4	12.0	14.3
5	4.5	5.1	6.5	11.2	15.5
6	4.0	5.3	7.4	11.2	16.6
7	5.0	6.5	8.1	12.3	16.9
8	5.1	6.0	6.8	10.8	16.3
9	5.0	5.6	8.2	11.5	15.5
10	4.5	6.1	7.6	12.5	15.8
11	3.5	4.3	6.6	11.6	17.6
12	3.5	4.7	6.4	12.2	17.3
13	5.1	6.5	8.1	13.3	16.8
14	3.8	5.5	6.5	12.2	16.8
15	4.0	5.4	5.5	10.8	17.0
mean hts	4.4	5.4	6.9	11.8	16.3

Weekly Heights (cm) of Vinca in SuperSoil

plant #	ht1	ht2	ht3	ht4	SuperSoil	Miracle-Gro
1	5.3	4.4	7.4	12.5	19.4	15.6
2	4.6	5.0	8.0	12.3	19.9	16.0
3	4.8	6.0	9.0	14.6	20.5	16.0
4	5.8	5.3	8.0	14.1	19.0	14.3
5	5.2	5.4	8.1	15.6	21.0	15.5
6	5.2	7.2	9.4	12.8	20.1	16.6
7	3.8	4.6	7.1	13.2	21.5	16.9
8	2.1	4.8	7.6	15.0	23.5	16.3
9	3.0	4.1	7.6	13.6	22.3	15.5
10	3.4	5.1	6.4	12.8	23.0	15.8
11	4.3	4.9	7.5	13.4	21.9	17.6
12	3.0	4.8	7.9	13.8	23.4	17.3
13	4.3	5.1	8.2	12.6	22.4	16.8
14	5.1	6.1	9.0	15.0	23.4	16.8
15	4.1	4.1	6.5	12.2	21.8	17.0
	4.3	5.1	7.8	13.6	21.5	16.3

P-value table for plant growth data.

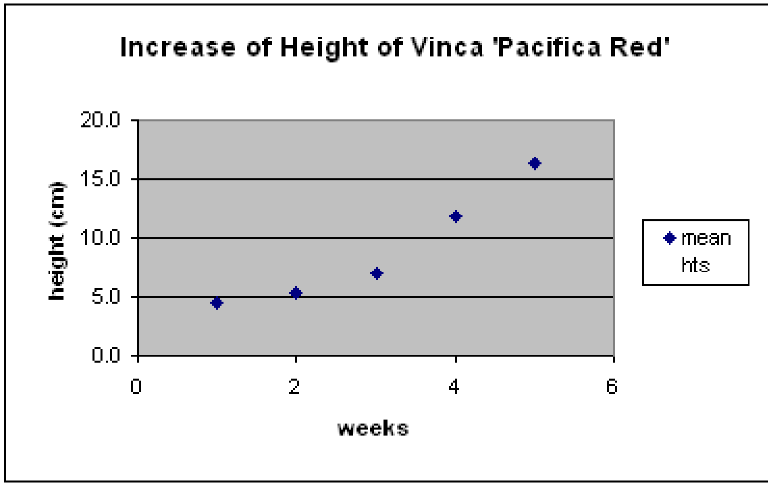
Anova: Single Factor

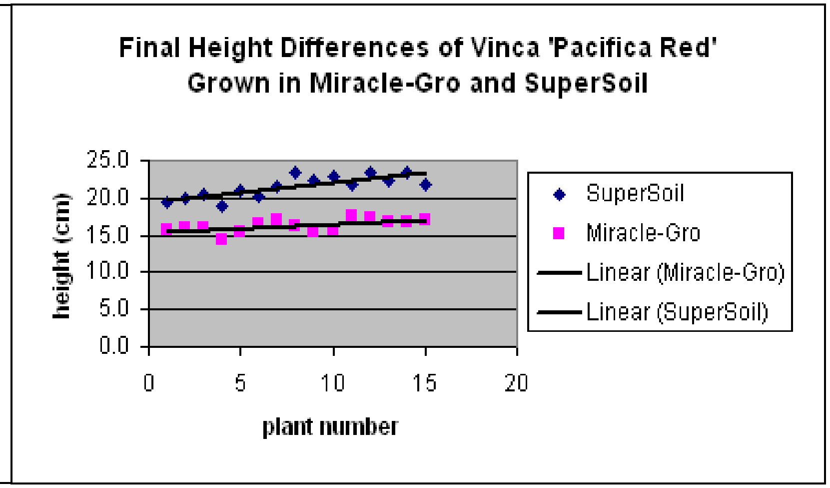
SUMMARY

Groups	Count	Sum	Average	Variance
SuperSoil	15	323.1	21.54	2.255429
Miracle-Gro	15	244	16.26667	0.736667

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	208.5603	1	208.5603	139.4076	2.18E-12	4.195982
Within Groups	41.88933	28	1.496048			
Total	250.4497	29				


Increase of Height of Vinca 'Pacifica Red'
height (cm)
20.0
15.0
10.0
5.0
0.0
0
2
4
6
weeks
mean hts


Final Height Differences of Vinca 'Pacifica Red' Grown in Miracle-Gro and SuperSoil
height (cm)
25.0
20.0
15.0
10.0
5.0
0.0
0
5
10
15
20
plant number
SuperSoil
Miracle-Gro
Linear (Miracle-Gro)
Linear (SuperSoil)

Designing a Fertilizer Trial for One Cultivar of Bedding Plants

A fun hortscience experiment for students is a fertilizer trial with several treatments of water-soluble fertilizer. Since Excel works best with 10 replicates/treatment, this will be better designed for 5 or fewer treatments (with one of them being the control, plain water). Refer to Lab 10-5 in the General Horticulture Laboratory Manual by D.W. Reed for procedures and suggested plants.

Your students could add to the experiment by testing water-soluble fertilizers against granular fertilizers (ammonium nitrate, ammonium phosphate), time-released fertilizers (Osmocote, Nutricote), specialty fertilizers such as Jobe's Houseplant Spikes, or organic fertilizers (blood meal, bone meal, fish emulsion, etc.).

For this experiment you will need approximate 90 plugs or liners planted with one potting mix into 10 cm pots (1 plant/pot). From the literature or an internet search, students can hypothesize what a good general fertilizer should be and could make up various solutions to actually determine an optimal fertilizer. Below is a suggested recipe guide for making fertilizer solutions that your students will use to test 9 fertilizer concentrations. The last treatment isn't necessary but will kill plants quickly if you want to make a point about fertilizer toxicity.

Water-soluble fertilizer recipes (based on a 20-10-20 analysis)

To make 10L of Stock Solution (equals 20,000 ppm N) add 1000 g of 20-10-20 to a large Nalgene bottle or other container that has a tight lid (buckets work well) and fill with water to 10L. Mix thoroughly. Your students can store each of the treatments in labeled containers and can water/fertilizer as needed.

Treatment (ppm)	Stock solution (mL)	Water	
0	0	10L	x
100	50	9950 mL	
200	100	9900 mL	x
400	200	9800 mL	x
800	400	9600 mL	x
1200	600	9400 mL	
1800	900	9100 mL	x
2400	1200	8800 mL	
4800	2400	7600 mL	

[x] If limited on plant numbers, use these concentrations with 5 replicates/treatment.

Researcher Contact Information

Carrie Whitcher
Primary Investigator

Lecturer
California State University, Chico
College of Agriculture
400 West First Street
Chico, CA 95929-0310
(530) 898-6879 office
(530) 898-5845 fax

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APPENDIX H

TABLE OF CRONBACH'S ALPHA RELIABILITY FOR OVERALL HORTSCIENCE ACHIEVEMENT TEST SCORES SHOWING ALPHA WHEN EACH ITEM IS DELETED

Item #	N of sample	N of variables	Cronbach's α if deleted
Overall Items	241	40	0.8159
1			0.8167
2			0.8125
3			0.8085
4			0.8112
5			0.8176
6			0.8156
7			0.8194
8			0.8098
9			0.8050
10			0.8101
11			0.8083
12			0.8074
13			0.8120
14			0.8158
15			0.8086
16			0.8094
17			0.8060
18			0.8094
19			0.8211
20			0.8073
21			0.8096
22			0.8130
23			0.8127
24			0.8138
25			0.8107
26			0.8091
27			0.8185
28			0.8103
29			0.8096
30			0.8124
31			0.8094
32			0.8067
33			0.8113
34			0.8129
35			0.8114
36			0.8126
37			0.8108
38			0.8113
39			0.8212
40			0.8214

VITA

Candidate: Carrie Lynn Whitcher

Permanent Mailing Address: 400 West First Street
Chico, CA 95929-0310

Degree: Doctor of Philosophy

Major Subject: Horticulture

Education:

B.S. Agriculture – Animal Science
California State University, Chico, 1989
M.S. Biology – Ecology
California State University, Chico, 2001
Ph.D. Horticulture – Texas A&M University,
College Station, 2005
Teaching Credentials (California):
Single Subject in Agriculture, 1991
Specialist in Agriculture, 1991
Introductory Life Science, 1991
Driver Training, 1995

Professional Experience:

Lecturer, College of Agriculture — 2003 – 2005
California State University, Chico

Associate Faculty, Butte-Glenn Community College — 2003 – 2005
Environmental Horticulture Department

Graduate Teaching and Research Assistant — 2001 – 2003
Texas A&M University, Dept. of Horticultural Sciences

Agriculture Instructor, Chico High School, Chico, CA — 1991 – 2001
FFA Advisor, Judging Teams Coach, Greenhouse Manager

Recent Publications:

Whitcher, C.L, M.D. Kent, and D.W. Reed. “Phosphorus Concentration Affects New Guinea Impatiens and Vinca in Recirculating Subirrigation,” submitted to *HortTechnology,* 2004.

Whitcher, C.L., D.H. Kistner, and H.R. Jacobson. “The Classification and Phylogeny of Nasutimimus and Termitomimus Revisited (Coleoptera: Staphylinidae, Aleocharinae),” *Sociobiology,* 2001.