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FAST PLANTS:
AN EVALUATION OF THE USE OF AN INNOVATIVE PLANT MATERIAL IN MIDDLE AND HIGH SCHOOL CLASSROOMS

A Dissertation Presented

by

JUDITH H. FISCHER

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University of Massachusetts in partial fulfillment
of the requirements for the degree of

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School of Education

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ABSTRACT

FAST PLANTS:
AN EVALUATION OF THE USE OF AN INNOVATIVE PLANT MATERIAL IN MIDDLE AND HIGH SCHOOL CLASSROOMS

FEBRUARY 1991

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A new plant cultivar, Fast Plants (Brassica rapa), originally developed for research purposes, shows great potential for improving science teaching and learning. The extremely short life cycle and petite size of the material, plus easy classroom maintenance procedures, suggest that Fast Plants may be an important vehicle for changing attitudes toward plants and plant study, and for changing classroom practice. This study has been undertaken to assess the usefulness and effectiveness of Fast Plants to middle and high school science teachers.

A group of middle and high school teachers were introduced to Fast Plants at a one-day workshop. 22 of those attending volunteered to use Fast Plants in their classrooms during the subsequent school year. Although teachers were not specifically asked to continue work with Fast Plants after the first year, their use of the innovation was documented through the three years of the study. Teacher response to the material was assessed using questionnaires, interviews, and classroom observation during the three years.

The final summative evaluation made at the end of the study indicates that the material was very useful in the classroom and a highly effective teaching tool. Teacher use of Fast Plants increased during the three years, with an expansion both in the numbers of classes in which the innovation was used, and in the ways the material was used. Increases in the time spent on plant study, in student use of live plant material, and in student learning as judged by their teachers were seen. The innovation had a positive effect on both students and teachers.

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CHAPTER 1

THE PROBLEM

Introduction

At the present time many are expressing concern about the quality and effectiveness of American science education. Since the publication in 1983 of A Nation at Risk [National Commission on Excellence in Education], a growing number of studies have pointed out shortcomings in American science education. The Educational Testing Service [1989] has reported that American students are emerging from high school so poorly prepared in science that less than 7% can handle college level courses. Math and science scores are not improving. In fact, Americans' achievement in science is falling to extremely low levels, compared with students in other nations. At the same time, the proportion of foreign graduate students study in math and science at American universities is increasing every year.

Science is also becoming increasingly important in a worldwide economic competition. More of even the most routine jobs require levels of scientific and mathematical skills beyond those of most students entering the job market. This situation can only increase in the future.

At the same time, "scientific literacy" is becoming increasingly important to a democratic society, where voters are being asked to make decisions about complex scientific issues, including nuclear energy, bioengineering, global warming, and acid rain.

School science does little to prepare "scientifically literate" citizens. Science classes all too often are only tedious lectures, textbooks and memorization, rather than problem solving and creative thinking about interesting aspects of the real world. Children's natural curiosity about the world about them is often stifled, rather than encouraged. Research shows that even by the middle elementary years, many students express a strong dislike for science. Unfortunately, this trend only increases the more science students take.

Part of the problem is that school science bears little relationship to the discipline of science. While all Americans study science in school, few ever find out what the discipline is all about, and see it only as a set of obscure facts, meaningless words, and abstract and unintelligible theories. Yet science is really a way of learning about the world by asking questions, proposing explanations, and testing them against available evidence. Science at its best is intellectually exciting, demanding discipline and imagination. It also should be lots of fun.

Two major issues in science education today are first, what is taught; and second, how it is taught. These issues are not new; they are the same ones that were addressed in post-Sputnik reforms of the 1960's. However, in spite of all the new curricula, demonstration projects, and innovations generated by those reform efforts, satisfactory solutions to these problems have not been found. Remarkably little has changed from a generation ago in either what is taught or the way the subject is taught.

Today there are a few encouraging signs. One of them is a new approach to the problem of 'how to teach,' based on constructivist theories on learning. Many now believe that students are not merely "empty vessels" to be filled with knowledge by an expert (the teacher), but that students need to be helped to construct their own knowledge. When using this approach, teachers become "facilitators," rather than "judges" or "experts." Students and teachers both become learners together. According to constructivists, students in science class students should be involved in first-hand exploration and manipulation of real materials, seeking increasingly broad, sensible, and useful explanations about phenomena in their everyday world. The emphasis should be on learning to ask questions, rather than memorizing answers; on intellectual rigor, rather than superficial coverage.

At the present time, there is little clarity about just what ought to be taught, in spite of all the textbooks and school curricula. In the past, as scientific knowledge expanded, so did the curriculum. This has resulted in superficial coverage of an enormous number of topics, as well as considerable repetition.

Many educators now question this approach, and suggest that depth may be more important than breadth. Many curricular reform efforts are underway, as both educators and scientists attempt to define just what science ought to be taught in the schools. One of the largest is a three stage effort undertaken by the American Association for the Advancement of Science. Its first report, Science for All Americans [AAAS, 1989], has defined the knowledge, skills, and attitudes that all students ought to acquire by the time they complete high school. Curriculum development and dissemination phases are yet to be completed. While the success of this, and other similar efforts, remains to be determined, one thing seems clear: school science ought to begin with those things in the natural world that are especially interesting or puzzling to students of particular ages, rather than just those topics teachers feel they must teach to "prepare students for the next level."

Perhaps the most difficult requirement for reforming science education, is the fact that the change must occur in teachers' underlying beliefs about both science and education, rather than simply in textbooks and curricular materials. Change is a long and slow process; perhaps especially so in education, where teachers tend to teach the way they remember being taught. If this is true, then developing highly structured "teacher-proof" curricula will never lead to basic reform in science education. Even the development of the best teaching materials will fail without changes in teachers' underlying beliefs about teaching, learning, and the nature of knowledge.

If the development of highly prescriptive curricular materials alone does not cause teachers to change their underlying assumptions about science, teching and learning, what else might be tried? One solution might be to provide teachers with new and innovative teaching materials to use in an open-ended way in the classroom. Rather than providing highly structured curricular packages of sequential lessons and prescriptive labs, teachers might be given a few suggestions for ways ways to use the material, and encouraged to use their own imagination to fit the innovation into their classrooms in any way that works best for them.

The recent appearance of an innovative botanical material, Wisconsin Fast Plants, with great potential for a wide range of applications in science classrooms offers the opportunity to test this approach. That is the focus of this study.

Teaching and Learning about Plants

This project takes as its point of departure the present state of teaching about plants in schools. Teaching about plants is neglected in American schools today.

Teachers spend less time on plants than on animals, and much of what they do is highly academic, repetitive, and dull. Much less space is devoted to plants in textbooks and lab manuals. The texts at all levels, elementary through high school, are remarkably similar, often with the same topics, activities and pedagogical approaches. Since teachers get a large proportion of their teaching ideas from text books, it is not suprising that there is so much repetition.

In an increasingly urban society, gardening, and caring for plants is a long way from the expereiences of many children. Teachers often express astonishment at their pupils' lack of familiarity with anything to do with plants. While most students have probably planted beans or corn in a plastic cup at some time or other, few have watched those plants mature, and fewer still have actually harvested seeds from a seed that they planted.

The focus of school plant study, as with other parts of science, is more apt to be vocabulary recall than concept development. Plant study tends to stress answers, rather than questions, memorization rather than understanding. What is taught all too often stresses the academic, rather than the practical, with little relationship to student interests and experiences.

With too many topics to cover, teaching about plants is often superficial. Teachers rarely spend more than a few weeks on plants, even in high school biology. Often plants are entirely left out, considered by teachers to be less important or less interesting than other topics. Sometimes teachers leave plants out beause they believe that the topics has been covered adequately in earlier grades.

In most textbooks plants and animals are approached as two completely distinct topics. Similarities and differences in plants and animals are rarely stressed. Ecological topics, where comparisons and contrasts between plants and animals might easily be made, are often at the end of the textbook; and with too many topics to cover, teachers often don't get that far.

Teachers are often poorly trained in plant science. Few have had more than a single botany course; many have not even had that. College biology courses often show a strong animal bias, reflecting the interests of the professors. It is rare to find teachers who have had a background in horticulture or the more practical and applied aspects of plant study.

The teaching of plant topics (like much of science) tends to be very traditional. Teachers draw on their own past experience, and model their teaching on memories of their own schooling. This is reinforced by the textboooks, which emphasize an approach that values memorizing specific facts, rather than developing broader, more powerful and useful explanations of how the world works. There are special problems associated with using living plant material in the classroom. Growing and maintaining plants is sometimes difficult in the classroom--space is often limited, natural lighting inadequate or non-existent. Wide fluctuations in room temperature pose additional problems, especially during school holidays. The extremely long life cycle of many plants, often measured in months rather than days, is another limitation. Time for preparing labs is extremely limited, and the need for a wide variety of living materials can deter even the most determined teachers. Often a large number of different plants are specified for particular labs, and teachers' limited botanical background makes it difficult for them to improvise.

Another drawback to plants is the fact that many students find them boring, who complain that "they don't do anything," or they "don't move." Student interest (or lack of it) seems to exert a strong influence on teachers' choice of topics to teach. Teachers, with little interest in plants themselves, are often all too happy to have an excuse to limit the time the spend on the topic. Students in turn, rarely have a chance to do anything that is interesting or fun with plants, which reinforces their already negative opinions about the subject.

The Innovative Material: Fast Plants

A major obstacle to teaching about plants has been the lack of good plant materials which work as well as small animals presently in common use. Mice, Drosophia, and microbes such as E. coli have been very important model organisms for biological research and teaching. All have rapid reproductive cycles, are easy to maintain in a wide range of lab settings, and have a stable pool of genetic material.

Until recently, no single satisfactory research model which met these criteria existed for higher plants. Now such plants exist in the "rapid-cycling" cultivars of the cabbage (Crucifer) family. One of these cultivars, Brassica rapa is the innovative material under study in this inquiry. Six "rapid cycling" Brassicas were developed by Paul Williams, a plant pathologist at the University of Wisconsin, to speed up his own research.

In 1970, while growing various Brassicas (one of the major groups in the Crucifer family) he noticed that a few plants of each species flowered much earlier than others. It occurred to him that it would help his own work if he could speed up the relatively long life cycles (six months to a year or more) of various species in this economically important group. At the same time it would also be useful to have very small plants that would grow well in crowded conditions; that had a highly uniform life cycle, high female fertility, rapid seed maturation, absence of seed dormancy; and that would flourish in soil, light and temperature easy to duplicate in any lab. He began a breeding program, taking the ten percent of the plants in each generation that most nearly met all the criteria, and crossing them, until all his criteria had been met. Over a 15 year period, Williams developed rapid cycling cultivars of six economically important species: three diploids (*B. nigra*, *B. oleracea*, and *B. rapa*); and three naturally occuring allotetroploids (*B. carinata*, *B. juncea*, and *B. napus*). (Further details about these six species can be found in Appendix A).

Williams also began using the plants in the classroom with both graduate and undergraduate students, and found them to be a highly successful teaching tool. It occured to him that the rapid cycling Brassicas might also be useful in teaching younger (K-12) students, and in 1985 he received a National Science Foundation grant to design simple and effective ways to grow and maintain the fastest of these rapid cyclers, *Brassica rapa* (which he called Wisconsin Fast Plants) for use in elementary, middle and high school classrooms. Funds were also provided to introduce a small number of teachers to the innovation and provide materials and equipment for them to pilot Fast Plants in their classrooms.

At the time this researcher's project was undertaken, Fast Plants had been used in only a few classrooms in Wisconsin. Preliminary results from the first pilot group suggested that the material held great promise as a way to improve both science teaching and learning.

Significance of the Problem

If science is about objects and events in the physical world, then students who are learning science need a variety of materials to help them. Good materials must satisfy a number of criteria. First, they should be appealing and interesting to students, stimulating their curiosity and helping them develop positive attitudes toward doing science. Second, they should be able to be easily used in the classroom by students (both male and female) of a broad range of ages and abilities. Third, they should be simple, safe, inexpensive and easy to maintain. Fourth, the materials should have flexibility, so that teachers can use them in many different ways.

Fast Plants seem to all fit these criteria, but their actual performance over time in classrooms remained to be determined. How closely would the material live up to its potential? What would teacher and student response be? How would teachers use the material? What groups of students would they use Fast Plants with?

Fast Plants also provided the opportunity to look at the process of implementing an innovation in some detail. Here was a chance to assess the innovation from the teachers' perspective in a variety of middle and high school classrooms. It also was an opportunity to measure the results of giving innovative materials to teachers in an open-ended way, rather than as part of a more tightly structured curricular package. Before specific uses became codified into a set of prescriptive activities in textbooks and lab manuals, it was an unusual chance to learn more about the ways in which teachers fit new ideas and materials into the existing complex fabric of their classroom practice. Finally, Fast Plants offered a way to learn more about the teaching of plant topics at the middle and high school levels.

It is hoped that the results of this inquiry will contribute to teaching practice and educational scholarship in a number of ways:

1) by increasing what is known about the particular innovation, Fast Plants, its effectiveness as a teaching tool, obstacles that might limit its usefulness in the classroom, and additional supports that might be helpful to teachers using the innovation.
2) by increasing what is known about the teaching of botanical topics in middle and high schools.
3) by adding to the knowledge about the implementation process, especially when an innovation is introduced by teacher choice, rather than by mandate, or as part of a structured curricular program.
4) by suggesting particular practical supports that might be instituted to help teachers more effectively utilize innovative materials and ideas in

their classrooms; recognizing teachers' sometimes paradoxical needs for both order and freedom, direction and choice, discipline and creativity, structure and autonomy, work and play in their teaching practice.

5) by encouraging locating other research materials that might be adapted for teaching purposes.

It is hoped that the results of the inquiry will be of use to classroom teachers, educators involved in staff development programs, teacher training, curriculum developers, researchers, and others interested in improving science education. It is also hoped that the findings will delineate strengths and weaknesses to introducing innovative materials in this way, and will enlarge our understanding of the ways in which teachers fit new ideas into their existing practice, and about the change process in general.

Problem Statement

There is a documented need to improve science education in America today. One part of this need is to change both what science is taught, and improve how it is taught. This inquiry addresses a single aspect of that need: to increase the attention given to plants, and to improve the methods used to teach plant topics.

Part of the solution to the problem is in the development of new teaching materials and methods which will actually work for teaching and learning in a variety of school environments. Fast Plants, a new plant cultivar with great potential as a classroom teaching material, has given rise to this study.

The specific purpose of this research is to evaluate the effectiveness and usefulness of Fast Plants in science teaching at the middle and high school levels. The study seeks solution to a highly practical problem: Can this new material which appears to have great potential, actually work in the classroom?

The task includes identifying and documenting what and how plant topics are taught in the classrooms under study, and assessing any changes which occur after the innovative material is introduced.   In this study, judgements on the effectiveness and usefulness of the innovation, Fast Plants, are made from the perspective of the teachers using the innovation, rather than from the perspective of specific (and externally determined) learning outcomes.

Research Questions

This research seeks answers to eight related questions about the performance and value of the botanical innovation, Wisconsin Fast Plants:

1. How well does the innovation perform in a variety of classroom conditions?
2. When provided with necessary equipment and supplies, how do the teachers in this particular sample use the innovation in their classrooms? Which classes or groups of students do they use them with? Do they continue to use Fast Plants after the first year? What happens to their level of use during the second and third years?
3. What effects, if any, does the innovation have on the teaching of plant topics? Does the amount of time given to plant study change in any way? Do the numbers and kinds of topics covered change?
4. What changes, if any, occur in hands-on activities and labs of the teachers who use Fast Plants? Are new and different activities undertaken with the new material, or are old activities repeated, substituting Fast Plants for other organisms?
5. Are there any changes in student learning, as judged by their teachers, through the introduction of Fast Plants into the classroom?
6. What is the personal response of teachers and students to Fast Plants? What effects does the introduction of Fast Plants have on teacher and student attitudes, feelings, and beliefs about plants and science in general?

7. Do the participating teachers feel that Fast Plants helped them to become better teachers, and/or to develop professionally?

8. What, if anything, do teachers share with colleagues and other professionals about Fast Plants?

Scope of the Study

The scope of the study is limited to assessing the effects of the innovation at the middle and high school level over a three year period. No elementary school teachers are involved in the study, although the innovative material also has great potential at this level.

This inquiry is limited to studying the effects the innovative material, Fast Plants, has in the classrooms of a particular group of teachers; a group of highly motivated professionals who volunteered to try out the material with their students.

This research is also limited in the way in which the innovation is evaluated. Assessment is made through the teachers' eyes. No direct assessment of changes in student performance or external measurmements of student learning are included.

Definition of Terms

Brassica: a large (over 2000 species) and diverse genus of the Crucifer family. Economically important examples include cabbage, kale, turnips, Chinese cabbage, broccoli, cauliflower, brussel sprouts, and rape.

cultivar: a cultivated variety of an organism; one that originates and is persistent under cultivation. Wisconsin Fast Plants (*Brassica rapa*) is an example.

Wisconsin Fast Plants or Fast Plants: the common name given to *Brassica rapa*, a cultivar developed by Dr. Paul Williams at the University of Wisconsin for his own research.

innovation: any of a wide range of new ideas or things related to classroom teaching: new teaching material, curricular material, teaching technique, management technique or the like.

rapid-cycling plants:refers to cultivars of six economically important Brassica species whose reproductive cycle has been significantly reduced over that of wild populations. Each variety is relatively homogeneous with respect to it morphology and flowering time. At the same time the plants still exhibit substantial genetic variation, making them useful in research.

Summary

This chapter reviews the current status of science education and of plant studies in the schools, noting that it is not always clear what about science ought to be taught, nor how it should be taught. Plants are often neglected in science classes, and are considered dull by many students. The teaching is often repetitive, and students have little opportunity to engage in true investigations using living plant materials.

A new plant cultivar, Wisconsin Fast Plants, offers an opportunity to improve science teaching generally, and specifically the teaching about plants. This study will assess the effects the innovation has on the science teaching in 22 middle and high school classrooms--whether the material changes the amount of time teachers devote to plant studies, changes what they teach about plants or how they teach the topic, or changes attitudes toward teaching and learning about plants, or science in general.

Chapter 2 reviews the literature on plant study in schools, implementation of innovations, professional development of teachers, and the change process.

Chapter 3 contains the details of how the study was carried out including descriptions of the teacher participants studied, the research design, interventions undertaken with participants, the instruments used to collect data, treatment of data, and possible limitations to the research.

Chapter 4 contains the findings of the study: the technical performance of Fast Plants in the classroom, the level of use of the innovation over a 3 year period, changes in time spent on plant study, changes in classroom lab work, changes in student learning (from the teachers' perspective), teacher and student personal response to the innovation, changes in teacher attitudes and beliefs about plant study and science in general, and evidence of teacher professional development through the use of the innovation.

Chapter 5 reviews the problem and methodological design of this study, and discusses the results of the research. Implications of the findings for teaching practice and future research are explored and a series of programs to improve the teaching about plants, and increase the use are Fast Plants are described.

CHAPTER 2

REVIEW OF THE LITERATURE

Introduction

The review of the literature is divided into two parts. The first surveys the literature on plant study in schools, beginning with the current state of practice with respect to teaching plant topics in schools, including textbook coverage of plants, resources for teaching plant topics, studies on teachers' background and attitudes toward plants, student interest in plant study, and student conceptual understandings about plants.

The second section reviews the literature on teaching practice, beginning with a review of studies calling for reform in American education, especially science education. Sections follow on a conceptual model of teaching and learning, student misconceptions and science teaching, school improvement studies, teacher's lives in schools, the problems teachers face in their work environment, professional development, models of change and implementation of innovations.

Contexts: Literature on Plant Study in Schools

This section discusses the literature on plant study, including a review of what is known about current classroom practice with respect to teaching about plants, and resources available to teachers on plants: standard textbook sources, ideas in teaching journals, books and articles on nature study, plants, and gardening, curricula from vocational education programs in agriculture, and materials on plants importance in the environment. Studies on teachers' academic background in botany and attitudes toward plant study, student interest in studying about plants, and misconceptions students hold about about concepts related to plants are also reviewed.

Teaching about Plants: The Current State of Practice

Discussions with teachers suggest that teaching about plants in schools today is usually limited, repetitive, and of little interest to most students. Wivagg [1987], in an editorial in The American Biology Teacher points out that there is a surprising lack of concern about the neglect of plant study at all levels, elementary through high school. In what may be the only extended discussion of the problem, Honey [1987] also writes about the relative neglect of plant study in schools. He suggests that plants should be part of everyone's general education for several reasons:

first, because they form a significant part our natural surroundings; second, because of their essential position in the food chain; and third, because of their economic and social importance, especially as food, to both developed and underdeveloped countries of the world. Honey stresses the need for students to have the opportunity to contrast and compare basic life processes in plant and animals, and suggests that at present the emphasis is almost entirely on animals.

There are far fewer articles on plants in science teaching journals than about animals. There are also fewer sessions on plant topics at professional teachers' meetings. Science methods textbooks do not stress the importance of teaching about both plants and animals, nor comment on the imbalance between coverage about plants and animals in schools. The same is true of textbooks.

Standard Textbook Approaches to Teaching about Plants

Because there are almost no other guidelines available, textbooks by default have become teachers' primary source for deciding how to teach about plants, and what to teach. A quick look at the various standard texts used at the elementary, middle and high school levels reveals several things.

First, elementary, middle and high school texts all look very much the same when it comes to plants: the same topics, the same activities, the same goals. Texts at each level often seem to be little more than watered-down versions of the next higher level. In three frequently used texts, the elementary <u>Health Science</u> series [Barufaldi, Ladd & Moses, 1984], a middle school text, <u>Focus on Life Sceince</u> [Daniel, Kasket, & Siegel, 1987], and a high school text, <u>Modern Biology</u> [Otto & Towle, 1985], one sees the same major concepts (plant classification, life cycles, nutrition, reproduction, and plant behavior) covered in the same way, often with the same activities. Structure, rather than function, is emphasized; chapters can be found on roots, stems, leaves, flowers, and seeds of plants. The assumption seems to be that by learning the name of something, students will automatically understand its function.

In one Heath <u>Science</u> text [Barufaldi, Ladd & Moses, 1984], students dissect tulips in order to see the reproductive structure. The authors suggest that as a result of this dissection, pupils will understand seed development. This seems unlikely, especially since few, if any, children have ever seen tulip seeds on the plants, and their own experience tells them that tulips grow from bulbs, not seeds. The result for students may be confusing at best. The same flower dissection activity with the same goals is found in middle and high school texts [Daniel et. al, 1987, Otto & Towle, 1985]. Similar repetitions can be seen in almost every topic in these three texts, as well as in other texts commonly used at all three levels.

This approach, with its heavy content emphasis, is diametrically different from one described by Harlen who suggests simply that pupils should have a wide range of carefully selected and interesting activities to help them construct the basic and useful idea that:

> "a wide variety of different living things called plants...feed, grow and reproduce in different ways. Many are green and produce the food they need through a process which needs light. Soil is a mixture of different things some of which are needed by plants to to grow." [1985,p. 79]

In the three texts plants are given less attention than animals. Modern Biology [Otto & Towle, 1985] devotes about 15% of its space to plants, Focus on Life Science [Daniel, Kaskel, & Siegel, 1987] gives less than 20% of the space to plants. In the Heath Science texts [Barufaldi, Ladd, & Moses, 1984], plant topics make up only about 8% of the material covered. The pattern is little different in other textbooks.

This conventional approach to teaching plant topics at all levels seems remarkably little changed from what was done a hundred years ago, when botany was first offered as a separate subject. Darwinian evolution was then a new and exciting idea, and its influence was clearly seen in an approach that stressed taxonomy, morphology and internal anatomy of representative plant and animal species. Today, the influence of the past persists; plant studies continue to have an odd, old-fashioned look.

Ideas for Specific Activities about Plants

Many good ideas for teaching about plants can be found in science teaching journals (even though there are far fewer articles than about animals). Space does not permit a complete survey here, but a few examples may suffice to show the range. Some articles suggest ways to use particular plants in the classroom: for example the dandelion [Knapp & Knapp, 1980], weeds and wild plants [Kallas, 1984; Nowak, 1985], grass [Loveless 1984], carnivorous plants [Merzie, 1982], the amaryllis [Mechling & Twiest, 1982].

Others describe activities based on various plant parts: seeds [Powell, 1984], flowers and flower parts [Maier, 1987; Clay-Poole & Sleanick, 1983; Slater, 1972], roots [Devonald, 1986; Jusaistis 1985], and leaves [Klein, 1981; Scharmann 1984]. Still others focus on plant processes: growth [Oxlade, 1985], photosynthesis [Stewart, Hawcroft and Bourne, 1974; Kendrick, 1981], and germination [Gill, 1982; Kordan, 1984; Bicak, 1986].

There are also articles dealing with the effect of environmental factors on plants [Mason, 1982; Oxlade & Clifford, 1981; Adams & Attridge, 1984; Bundy, 1983], plant genetics [DeYoung, 1983], insect-plant relationships [Aston, 1987; Fry & Wartten, 1979], plants as food [Kim, 1981; McKie, 1984], or field studies using plants [Tomley, 1983; Wilson & Oldham, 1984], Articles also have recently been written on hydroponics [Garner, 1987], vegetative propagation [Karmer, 1983], cellular structure [Honey, 1984], and plant cell processes [Gayford, 1984; Kamrin & LaVan, 1984].

There has been a slight increase in the coverage of plants in the past year or so. Since 1989 articles in The American Biology Teacher have included Brookman's [1989] An outdoor lab exercise using leaf traps, Campbell's [1989] Familiarizing students with some edible & posonous wild plants, Thomson & Neal's [1989] Wind dispersal of tree seeds & fruits, Seligmann & Thompson's [1989] Using computers in measuring transpiration rate, Hafner's [1990] Fast Plants--rapid cycling Brassicas, Neill, Neill & Frye's [1990] Is there a correlation between rainfall amounts and the number of stomata in cottonwood leaves? and Nichol's [1990] Hydroponics & aquaculture in the high school classroom. In The Science Teacher there have been articles on roots [Hershey, 1990], plant pollination [Foote, 1990], soil science [Eswaran, Kupelian, Levermann, & Yost, 1990], while in Science and Children, articles have appeared on pumpkins [Johnson and Stone, 1989], plant taxonomy [Gotsch and Harris, 1990], Van Helmont's experiments [Dempsey, 1990], flower dissection [Vibe, 1990], maple trees [Hogan, 1990], and plant life in bogs [Hanif, 1990].

Resources from Nature Study

Another rich source for plant activities is found in books and articles on nature study. Comstock's Handbook of Nature Study [1986], first published in 1911, remains a classic. It is full of useful information and remains an excellent source for teaching ideas about common plants just outside the schoolhouse door, a resource all too rarely used by teachers. Lawrence Durrell's Practical Guide for the Amateur Naturalist [1986] is also helpful, as is Rutherford Platt's This Green World [1986]. This book, recently republished with some updated material, is as fresh as it was when originally written forty years ago. The book explores the many remarkable ways that plants solve basic problems of survival: energy needs, transport, and ways to insure the survival of each species. It could provide an outline for a very interesting study of the plant world. Other books of interest include Galston's [1981] Green wisdom: The inside story of plant life, and the recent and excellent Wily violets and underground orchids: Revelations of a botanist [Bernhardt, 1990].

Roth's [1984] The plant observer's guidebook provides an introduction to field botany, and is an especially useful resource for teachers who want to include field botany. Wildflower guides, readily available in most bookstores, are excellent classroom resources. Examples include The Audubon Society field guide to North American wildflowers: Eastern Region [Niering & Olmstead, 1979], The Audubon Society field guide to North American trees: Eastern region [Little, 1980]. The Peterson Field Guide Series include A field guide to the wildflowers of the northeastern and central states [McKenney & Peterson, 1958], A field guide to trees and shrubs: Northeastern and central North America [Petrides, 1958], and A field guide to the ferns and their related families of northeastern and central North America [Cobb,1963]. A guide to enjoying wildflowers [Stokes & Stokes, 1985], introduces readers to 50 common wildflowers representing a wide range of lifestyles and habitats. Weeds in winter [Brown, 1976], includes drawings of many common weeds and wildflowers of the northeastern United States in the winter, and the two volume Manual of the grasses of the United States [Hitchcock, 1971] are also useful classroom resources.

Learning about Plants through Gardening

Nelson [1988] and Gwynn, [1988] describe recent programs in gardening designed for student to do either in the classroom or outdoors. The National Gardening Association has published two books on gardening, The Youth Gardening Book [Ocone 1983] and Grow lab: a complete guide to gardening in the classroom [1988]. Both are written for use in elementary and middle schools, but could be adapted for high school students. In these books, gardening is used as a way to integrate many separate subjects including science, math, social studies, history, and art; and to help pupils improve their skills in problem-solving.

Other major projects in garden education include the Life Lab Science Program in California, and Meals for Millions in Arizona. Local groups that have also developed gardening programs for children include the San Francisco League of Urban Gardeners, the Bridgeport (CT) Urban Garden Program, the Teacher Training Institute at Shelburne Farms (VT), and the New Alchemy Institute (MA). The New York Botanical Gardens has had a long interest in children's gardening projects, and devoted one issue of its periodical, Brooklyn Botanic Garden Record [Pesch, 1984], to articles about children's gardening programs around the world. An interesting English example is a curricular unit on gardening for "less academically motivated pupils" in the 14-16 age range [Wilkinson & Bowers, 1977].

Much useful information can be found in a wide range of "how-to" gardening books, available in most public libraries. One example is the series of small booklets published by the John Henry Company [1976] on various subjects, such as caring for flowering plants, plant propagation, and plant pests. A book with the intriguing title, Blue corn and square tomatoes [Rupp, 1987], includes interesting information on tomatoes (sometimes square), corn (sometimes blue), as well as other commonly grown garden vegetables. Two other excellent sources are Plants in action: A scientific background to gardening [Hibbert & Brooks, 1981], written to accompany an English BBC television series, and VNR color dictionary of herbs and herbalism [Stuart, 1979].

Resources from Vocational Agriculture Training Programs

A rich resource little known to most science teachers, are materials developed for vocational classes in agriculture at the high school level. Extensive curricula on many plant topics have been developed by nearly every state and are available through ERIC.

The U.S. Department of Agriculture, in an attempt to encourage more teaching about food and agriculture, has recently published a bibliography, Resource guide to educational materials about agriculture [1986]. It includes educational materials available from public and private sources. Although there has been little concern about the problem in this country, the Israelis noted the lack of attention to agricultural problems in American textbooks, and have rewritten parts of the Biological Sciences Curriculum Study (yellow version) textbook to more adequately the importance of agriculture in their economy [Blum & Silberstein, 1979].

The Importance of Plants to Society

In American schools, plant studies are not usually connected with societal issues; the relationships between plants and human needs are rarely discussed. Yet environmental problems such as acid rain, the greenhouse effect, deforestation, and world food supply are taking on global importance. Two volumes of published papers from the 1984 Bangalore Conference, Science and Technology Education and Future Needs [Rao, 1987; Baez, Knamiller & Smyth, 1987], point out the limited teaching worldwide about important agricultural and environmental issues. Both volumes also include many thoughtful articles suggesting new approaches to teaching about these issues in the classroom.

Two atlases based on the GAIA hypothesis [Durrell, 1986; Myers, 1986] are excellent resources for teachers interested in helping students develop understandings about the interrelationships between plants, animals and the physical environment. The GAIA hypothesis postulates that life itself regulates physical and chemical conditions of the earth's surface, atmosphere and ocean, rather than life being entirely dependent on the physical environment. Both books include many maps, charts, graphs as well as text.

Green inheritance: The world wildlife book of plants [Huxley, 1985] documents the destruction of the world's plant heritage, a topic that has been receiving increased attention recently. Also useful is Blueprint for a green planet [Seymour and Girardet, 1987]. Discussions of the plants' importance to the environment can also be found in many popular periodicals. Recent examples include Life Magazine's special Earth Day [May, 1990] edition, an article on plant hunters in the National Geographic [Gibbons, 1990], and "Deforestation in the tropics" in Scientific American [Repetto, 1990].

Oakwatch [Flegg, 1985] follows an oak tree through the year, and describes the relationships and interactions of insects, animals and other plants associated with it in its local environment. It suggests a set of studies that students might do using a single tree as an ecosystem. A similar approach is taken in an article in the National Geographic, "Life in a nutshell" [Moffett, 1989]. The illustrations and diagrams are especially clear in Nature at work [1978], another book which focuses on the interactions between plants and animals.

Teachers' Background and Attitudes toward Plants

One reason why there is so little teaching about plants seems to be the limited background in plant science of most teachers. A large number of elementary teachers have studied no biology in college. Things are little better for middle and high school teachers with undergraduate degrees in biology, where zoology and the training of pre-med students dominate, and most biology majors have had only one traditional botany course, at best.

Teachers' poor attitudes toward plants often reflect this limited training. Carrick [1983] correlates teachers' greater interest in animals with their higher qualifications in zoology. Brodie [1964] points out the links that exist between teacher and student attitudes and achievement, while Napier and Riley [1985] document a relationship between high teacher interest and support, and student motivation and achievement in science.

Student Interest in Studying about Plants

Studies also indicate a student preference for animal, rather than plant study. Wandersee's [1986] research on seventh graders in New York showed a strong preference for studying animals. Many preferred to study animals because of their similarities to humans (they move, eat, see, make noise, can learn, have mates, give birth and raise their young). Dawson [1983] found that while neither 12 year old boys or girls had a strong interest in studying plants, the boys' interest was lower than the girls'. Studying 'common wild flowers' placed 20th on the girls' lists, while the highest placing plant topic was 77th on the boys' lists. In England 10 and 11 year old girls expressed greater interest in biological than in physical science topics [Kelly, Smail and Whyte, 1981]. Gardner [1975] pointed out that greater interest in the study of plants by girls may make plant study less attractive as a serious subject of study, while Parker and Rennie [1986] have suggested that teachers direct girls toward certain subjects (such as plants), and boys to others.

Other researchers have noted a general deterioration in positive attitudes toward science with age. Bohardt's [1975] study shows a decline of positive attitudes toward science from grades 4-8. Cannon and Simpson [1982] discovered that while science achievement of seventh grade students in North Carolina increased from the beginning to mid-year of seventh grade and then leveled off, positive attitudes toward science of both boys and girls of all abilities decreased, as did their motivation toward high achievement. Seventh grade is often students' first formal exposure to science as a separate discipline. All of this points to a continuing vicious circle, in which teachers teach in the way they were taught, and students pick up teacher attitudes, only to repeat the cycle with the next generation.

Many teachers find it very difficult to grow plants in the classroom. Space is often at a premium, and natural light limited. In some schools science classrooms don't even have windows. Greenhouses built in the 1960's and 1970's are now boarded up, or used only for storage--

victims of the energy crisis, funding cuts, as well as lack of teacher time and interest. The long life cycle of most plants, often a year or more, is another major impediment to their use in classrooms. So while students have plenty of opportunities to gain what Polanyi [1958] calls explicit knowledge (clearly articulated facts and theories), there is little chance to gain tacit knowledge (get the feel for phenomena). The joy of watching a living plant grow and develop is simply not available to most students.

Student Misunderstandings about Plants

As a consequence, pupils' understanding of basic plant concepts and their ability to apply these ideas in any meaningful way is extremely limited. This can be seen in students' scores of various national examinations. For example, recently published scores on the National Assessment of Eductional Progress examinations [Science Report Card, 1988] indicate that while students' knowledge of scientific facts has increased slightly, their ability to apply scientific reasoning to actual problems remains very low. These findings are not unique to America. English national test results indicate thaat less than one-third of 15 year olds understood that plants carry out respiration, or that during photosynthesis green plants take in carbon dioxide [Gamble, Davey, Gott, & Welford, 1985].

A large body of research on conceptual understanding shows that students' own explanations can be quite different from accepted scientific views. These misunderstandings are very resistent to change, and can impede student learning. Good introductions to misconceptions can be found in Driver [1983], Driver, Guesne and Tiberghien [1985]. and Osborne and Freyberg [1985].

Physics topics still dominate the literature on student misconceptions, but there is a small and growing body of data on pupils' understandings about plants. Bell [1981] studied childrens' understandings of the word "plant," and discovered that unlike biologists who classify living things as either plant or animal, children often use a much narrower meaning of the word. Many believe that weeds are not plants, nor are seeds, nor cabbages (which are "vegetables"). Although with age there is an increase in the number of pupils who use "plant" as scientists do, more than 10% of 16 year olds surveyed still believed that a carrot was not a plant. In another study Okeke and Wood-Robinson [1980] found that 40% of the Nigerian secondary biology students who they interviewed were not aware that plants could reproduce sexually. Biddulph [1984] reported research in which only 5% of students held a view of the life cycle of a flowering plant similar to a biologists' view.

Bell [1985] in a review article of several studies on students' understanding of plant nutrition finds that many secondary students hold ideas about plant nutrition that are different from those currently accepted by scientists. These include different meanings for words like "food" and "chlorophyll," little understanding of the importance of either food or energy in plant metabolism, a belief that food was taken in rather than produced, limited or confused understanding of the relationship of photosynthesis, respiration and water transport, and differing explanations of photosynthesis.

Simpson and Arnold [1982b] studied 12-13 year old pupils' understanding of photosynthesis, respiration, breathing and digestion and found that a substantial number of these students believed that plants either did not use air, or used it in "opposite ways to animals." Respiration and breathing was confused by many students, as was the relationship between food, digestion and energy. Furthermore, many did not understand chlorophyll's function in photosynthesis.

In another study Simpson and Arnold [1982a] investigated students' understandings of prerequisite concepts for a full understanding of photosynthesis. They found that many students' difficulty with understanding of photosynthesis grew out of misunderstandings about prerequisite concepts including gases, energy and food, and what should be classified as "living things." Difficulties also seemed to arise from the level of abstraction in the concept of photosynthesis itself.

The Science Processes and Concept Exploration (SPACE) Project [Harlen, 1987] has been attempting to discover the ideas children hold about a range of concepts about the natural world. A recent SPACE report, Growth [Russell & Watt, 1990], describes not only the range of ideas children hold about this concept, but successful interventions teachers which can help students change existing mistaken ideas. In a 1984 review of intructional material on plants and photosynthesis, Smith and Anderson point out how resistant to change student understandings are, and note that teacher awareness alone does not necessarily lead to success in changing existing explanations.

Other studies have focused on relationships between student misunderstandings and textbooks. Barrass [1984] finds that students are often confused about photosynthesis and respiration as described in their textbooks. The confusion may develop from considering photosynthesis and respiration as "opposite" processes that occur in either plants or animals, or from various meanings given to the word "respiration" (especially the everyday meaning, "breathing" and the scientific meaning, "cellular process"). Roth [1985], in a study about the difficulties middle school students have in learning about photosynthesis from text books, suggests that much of their difficulty comes from reading strategies that do not help them modify existing misconceptions.

Other researchers have been developing written materials to help diagnose student misunderstandings about plants. Examples include Martin's [1979] diagnostic instrument for determining botanically related misconceptions of beginning college botany students, Treagust's [1988] instrument for assessing students' understandings of photosynthesis and respiration, and Biddulph's [1984] instrument to determine pupils' understandings of plant nutrition.

New ways to teach specific plant topics which take pupils' notions into account have been developed by Bell [1985], and Bishop [1986]. Project LEAP at Cornell is utilizing concept change strategies to adapt OBIS and SCIIS activities about plants for elementary students. Barker and Carr [1989] describe a constructivist approach to the teaching of photosynthesis which has been used with encouraging results in middle school classrooms.

Contexts: Literature on Teaching

The literature on teaching is large and varied. The discussion of the literature in this section focuses on a number of specific aspects of teaching related to the questions explored in this inquiry: calls for reform in science teaching, the constructivist model for science teaching, school culture and its improvement, teacher professional development, models of change, and implementing innovations in the classroom.

Science Teaching: The Need for Reform

Beginning with the short report of the National Commission on Excellence in Education, A Nation at Risk [1983], there have been many who have pointed out the need to reform American education, and science education in particular. Other examples include Paideia proposal [Adler, 1982], High school [Boyer, 1983], A place called school [Goodlad, 1983], The shopping mall high school [Powell, Farrar & Cohen, 1985], and Horace's compromise [Sizer, 1984].

Recent studies have suggested various ways to improve American education and increase the nation's ability to compete economically in a global economy. Examples include ACTION for excellence: A comprehensive plan to improve our nation's schools [Task Force on Education for Economic Growth, 1983], Making the grade [Twentieth Century Fund, 1983], America's competitive challenge [Business-Higher Education Forum, 1983], Education and Economic Progress [Carnegie Corporation, 1983], and Making America Work [National Governors' Association, 1987]. Some, including Tomorrow's teachers [The Holmes Group, 1986], and A nation prepared: Teachers for the 21st century [Carnegie Forum on Education and the Economy, 1986], have focused on the need to improve the quality of teachers if lasting reforms are to be made in American education.

The particular needs and shortcomings in science education have been detailed in numerous studies. Notable examples include Science and engineering education for the 1980's and beyond [National Science Foundation, 1980], Educating Americans for the 21st century [National Science Board, 1983], Science education in the United States [Exxon Education Foundation, 1984], and an entire issue of Daedalus [Spring, 1983] devoted to scientific literacy.

American student achievement in science is compared (often unfavorably) with students in other countries in Science education in global perspective [Klein & Rutherford, 1985], and Scientific achievement in seventeen countries [International Association for the Evaluation of Educational Achievement, 1988]. Periodic reports on science achiement by American students in The science report card [Mullis and Jenkins, 1988], shows a continuing decline. An annual report, This year in school science, documents the current status of a single aspect of science education--teaching, learning, or curriculum. See for example the 1988 volume, Science teaching: Making the system work [Champagne, 1988].

A major attempt to reform science education was begun in 1985 (the year Halley's comet made an appearance) by the American Association for the Advancement of Science.

Project 2061 is named for the next year in which the comet will appear, by which time it is hoped the proposed reforms will have been fully implemented. The project is divided into 3 stages. Phase I (completed), included the development of an overview of the knowledge, skills and attitudes that were felt to be important for all students to acquire during their schooling, This has been published in a report, Science for all Americans [American Association for the Advancement of Science, 1989], along with more detailed reports in five basic subject-matter areas in science including biology. Phase II, now in progress, intends to develop a series of alternative curriculum models, recommendations for change in teacher education, new assessment procedures, and ways to encourage the development of innovative teaching materials and technologies. In Phase III, colloborative efforts will be launched to help teachers turn the projects' abstract ideas into specific concrete activities, appropriate to their own classrooms.

A New Model for Teaching Science

During the past decade a new model of teaching has been emerging. The model is based on constructivist ideas about learning. A good introduction to the subject can be found in Fosnot's [1989] Enquiring teachers, enquiring learners. Another recent work is "The having of wonderful ideas" and other essays on teaching and learning [Duckworth, 1987].

Articles by Resnick [1983] and Posner, Strike, Hewson, & Gertzog [1982] discuss the psychological and philosophical underpinnings of constructivist ideas. Constructivist thinking draws its ideas from a variety of resources: Kelly's [1955] work on personal constructs, Polyani's [1958] notions on personal knowledge, Britton's [1969] and Barnes [1975] work on language, as well as the work of Piaget.

Constructivist ideas have been particularly appealing to many science educators, for whom the old-fashioned didactic approach to teaching increasingly has seemed inappropriate, and inductive approaches have proved unworkable. Science educators increasingly have begun to look at the way scientists work for a model of science teaching. In this respect, the work on the nature of science of both Popper [1972] and Kuhn [1963] have been especially important. Good general introductions to the nature of science, the methods that scientists use, and to learning in science can be found in The nature of science [Aicken, 1984], The scientific attitude [Grinnell, 1987], and Learning science [White, 1988].

Applying the ways scientists work, and constructivist ideas of learning as conceptual change is very difficult for teachers to put into practice. Generally, they continue to teach science in the same ways they learned it in school. Anderson and Smith [1985] provide a succinct statement of the application of constructivist ideas to science teaching, and how teachers can move toward this new way of teaching. Also useful is an article by Osborne and Wittrock [1983].

Science educators are just beginning to develop specific techniques to help teachers make major changes in their teaching methodologies that reflect constructivist thinking. One approach, which focuses on helping students make better use of science process skills, is described in _Teaching and learning primary science_ [Harlen, 1985] and _Developing science in the primary classroom_ [Harlen and Jelly, 1989]. Although both these books are written for primary teachers, many of the techniques are equally useful for middle and high school teachers.

Teachers: Their Lives in Schools

Some studies have attempted to describe teachers and the world which they inhabit, their day to day existence, the problems they face, and their attempts at professional development. Especially perceptive in describing teachers' life in the school is the work of Jackson [1968], Lortie [1975], Sarason [1982], and Lieberman and Miller [1984]. All address the problems and rewards teachers face within the social context of schools, and were written about aspects of school life that have previously received little attention.

Jackson's ground breaking work [1968] focuses exclusively on elementary classrooms, and is drawn from extended visits to four classrooms. Sarason [1982] was interested in the complexities involved in instituting change in schools, and points out the importance of including all groups in the community (including teachers) in school improvement efforts. Lortie's [1975] work is a sociological study of the teaching profession from the teachers' perspective. Through extensive interviews and observations he looks at many aspects of the teachers' world, including recruitment patterns, working conditions, the effects of the isolation on teachers, and the rewards teachers feel they gain.

In _Teachers, their world, and their work_, Lieberman and Miller [1984] deal primarily with urban schools, looking at schools from "the inside out," using case studies to describe life in both elementary and secondary schools. Their goal is to help teachers take more control over their own professional development by greater understanding of the complexities of their lives in schools.

Teachers Speak for Themselves

Much can be learned about life in the classroom from teachers' own writing. While researchers tend to look for generalities, teachers tend to think in terms of specifics, storing their knowledge as a set of stories of classroom experiences. Wigginton [1986] describes his own growth and development as a teacher, his ideas about characteristics which good teachers have, and his own views on how to continue to develop personally and professionally. Other examples of teachers who offer personal insights on being a teacher include Kohl [1984], Ashton-Warner [1963] and Paley [1979 and 1981].

Some researchers have interviewed teachers, looking for patterns in their daily teaching practice. Macrorie [1984] gives us glimpses of twenty different teachers who work at various grade levels, and finds that the normal form of teaching is "pass[ing] on the accepted knowledge of the world and get[ting] it back from students on tests" (p. xi). This is probably a major limitation on what schooling achieves. Other books about teachers' experiences in the classroom include Ray's [1985] set of fourteen "self-portraits" of teachers and former teachers, which focus on the "occupational hazards" of teaching, and Gibson's [1973] teacher interviews, focused on how teachers see their work, and cope with change.

Teachers: The Problems They Face

Other studies focus on problems that teachers encounter in their work. McLaughlin, Wallin, Pfeifer, Swanson-Owens, & Yee [1986] suggest that the enormity of problems teachers face daily often make it impossible for them to meet their own goals. This can lead to either apathy or "burn-out." Cohn [1987] interviewed a large number of teachers in Dade County (Florida) and found that the problems that seemed to affect all teachers included uncooperative parents, unwilling students, an overload of paperwork, and central office control. These problems cause teachers to feel a lack of professional respect which often results them to leave the profession. It also discourages others from entering the profession.

In The complex roles of the teacher, Heck and Williams [1984] describe the various, and occasionally conflicting roles that teachers must take on in their work: teacher as person, colleague, "understander" of students, faciltator of learning, communicator to parents, researcher, program developer, administrator, decision maker, and professional leader. Sykes [1983] who also describes the problems teachers face, suggests that rather than focusing on screening out poor teachers, there is a need to create "magnets" to draw the best into the profession.

Building a Professional Culture in Schools

A considerable literature exists which describes the existing professional culture in schools and suggests possible ways to improve it. Devaney and Sykes [1988], look at reasons why a professional culture in schools is important in the first place, and point out that each school has its own particular culture, which never can be duplicated exactly in another setting. Successful school culture is purposefully built from clear ideas shared by the staff about how the students in that setting learn best and how teachers teach best. Cooper [1988] suggests that building a professional culture in schools is methodologiclly complex, politically sensitive, and intellectually intricate.

Joyce [1986] stresses the importance of teacher involvement in the decision-making process in schools, and suggests that schools should be redesigned to encourage the development of colleagiality among teachers. Green [1986] discusses the need for increased dialogue between policy makers and teachers, and the need for policy makers to change their role from a regulatory one to a supportive one, which he suggests will encourage innovative approaches and teacher experimentation in the classroom.

Teachers as Leaders: The Quest for Professional Development

Whereas some who have been interested in improving schools see teachers as just one of many players, others see their role as central to educational change. Maeroff

[1988] argues that teachers themselves must become leaders, and that they cannot leave important decisions about childrens' education to others. It is they, as professionals, who largely create the classroom learning environment. He suggests that while earlier school improvement efforts stressed the importance of developing relationships and partnerships between various groups in the school community (both inside and outside the school itself), the best way to transform schools is by empowering teachers through developing teacher professionalism.

Little [1988] points out the importance of teacher leadership plays in changing the culture of schools. Lieberman, Saxl, and Miles [1988] examine the ideology and practice of teacher leadership, looking at the skills of teacher-leaders, and the ways in which they work to develop collegiality. McLaughlin and Yee [1988] suggest that teaching is satisfying to those involved in it for a wide variety of reasons, and that career development is a highly individuated process. They suggest that it is important to acknowledge the multifaceted, individuated nature of teaching careers, and to organize rewards which recognize this.

Teacher Professional Development: Stages of Growth

A number of researchers have examined teacher growth and professional development. Fuller [1969] studied the changes pre-service teachers make, and developed a model of teacher growth to describes the steps individuals take as they move from concerns about self, to concerns about management, and finally to concerns about student learning. Symington and Osborne [1985] studied the professional development of elementary school teachers with respect to science teaching. They suggest that although many primary teachers do not have a strong background in science, professional development programs that only teach them more content often are not helpful, because this only reinforce the teachers' ideas of science as imparting a set of facts and explanations, rather than as a process of thinking. Miller and Ellsworth [1983], looked at changing patterns of professional growth in a group of teachers over a two year period, and suggest that teacher growth develops out of three overlapping needs: the need to increase knowledge, to change attitudes, and to alter classroom practice.

The Change Process in Educational Institutions

A large body of literature exists on the change process, especially as it relates to schools and teaching. Fullan [1978] examined educational change in institutions. He describes five elements that must be transformed for successful change at the institutional level: 1) structure or organization of the group, 2) materials,

3) behavior, 4) knowledge and understanding, 5) participants' value commitments or internalization of change. The last three refer to changes that must take place in individuals, and must take place before either changes in group structures or changes in materials can take place.

Little (1986) examined organizational strategies of programs in professional development, and identified four criteria for successful staff development programs: 1) they must take place in a collegial atmosphere where teachers can develop shared understandings and commitment; 2) teachers must be involved in the training and the implementation of the program; 3) the focus of the program is on problems in curriculum and instruction that the teachers deem to be significant; and 4) a commitment by the developers of the programs to long-term continuous support of the teacher participants.

In Learning Change [1990], Lester and Onore describe a four year a professional development program which they directed in a single school district. The authors believe that lasting change in classroom practice occurs only if teachers are able to uncover and reformulate their beliefs and attitudes about teaching and learning, and especially their underlying assumptions about the nature of knowledge. Stories about teachers in the program are used to show the difficulty, complexity, individualistic and idiosyncratic nature of the change process (or lack of it). The authors conclude from their research that school change can only occur from the inside out, through change in individual teachers rather than by administrative mandate.

Hall and Loucks [1978], developed a model of the change, the Concerns Based Adoption Model (CBAM) which describes a series of stages that teachers move through as they deal with any innovation in the classroom. Their model is based on six assumptions about the adoption of any innovation: 1) Change is a process, not an event. 2) Interventions to encourage the innovation must focus on the individual teacher. 3) Change is a highly individualistic experience. 4) Teachers go through distinct stages in their perceptions and feelings about any change, and follow a series of steps as they implement an innovation. 5) Individual diagnosis and assistance for individual teachers by staff developers best facilitates change. 6) Staff developers need to exhibit flexibility in working with individual teachers, and organizations supporting the change.

The Concerns Based Adoption Model (CBAM) views change from three perspectives: Stages of Concern (the concerns individuals express about an innovation), Levels of Use (how the innovation is actually used), and Innovation Configuration (ways in which the innovation can be adapted to the needs and styles of specific individuals).

Enochs & Harty [1983] reviewed the literature on implementing innovations, and developed a way to quantitatively examine teachers' implementation proneness. Their Implementation Proneness Typology uses situational probes to assess teachers' assertiveness, surgency, conscientiousness, venturesomeness, imaginativeness, shrewdness, experimentiveness, self-sufficiency, humanistic classroom control ideology, and internal locus of control. Rogers and Shoemaker [1971] studied the patterns by which innovations are adopted and found that the first people to adopt a new idea were generally young and venturesome, liked risks, were viewed by others as being successful, and felt that the outcome of events was in their own control. Brooks and Hounshell [1975] found that individuals with an internal locus of control (i.e., who felt that the outcome of an event was in their own control) were more apt to try to implement an innovation than individual with an external locus of control (who felt that events were controlled by others).

Loucks & Sacchie [1983] note the importance of a "local facilitator," someone who has the time, skills, clout and resources to be the "cheerleader" (building commitment), the "linker" (bringing in outside experts and linking resources and expertise within the district), and the "trouble-shooter" (helping teachers solve problems) in successful implementation of innovations. Effective external facilitators have a high degree of credibility with teachers, and are able to work with them as both learners and teachers. Havelock [1973] also stresses the importance of the "change agent" in implementation of innovations.

Other studies point out the role that curricular materials themselves play in successful implementation. Van Den Akker [1988] finds that carefully designed curricular materials can improve implementation itself, especially in the early stages of implementation. Fullan [1985] says that the development of clear and validated materials, active administrative support, focused staff development or inservice programs, the development of staff collegiality, and selective uses of external resources (people and materials), can influence the actual classroom implementation. Stenhouse [1987] notes that to be successful innovative curriculum must not only improve student learning, but also help teachers improve their craft. Teachers develop professionally not by a change in heart but by critically reflecting on their own professional skills, and refining their teaching skills.

Ruddock and Kelly [1976] point out that mandating the adoption of an innovation does not necessarily lead to actual implementation in the classroom. A number of issues need to be considered, especially respect for the teachers' professional backgrounds, and their receptiveness to the proposed change, if successful dissemination of an innovation is to occur. The relationship between the innovation and teachers' current practice also needs to be carefully considered, as well as the teachers' opinions of the capabilities of their students, and the limitations of the particular classroom or school situation in which they work. A level of trust must be developed between teachers and innovators. Multiple strategies should be employed to make sure that the innovation is actually internalized by teachers. Teachers need to have a contributing role in the implementation. For personal and professional growth to occur, their own creativity must be engaged in the process.

Summary

Several points might be noted about the literature surveyed for this research. There is a real need to increase the amount of attention given to plant study in schools. Often biology and life science teachers do little teaching about plants, and when they do so, they teach in the ways they remember being taught, using textbooks that reinforce an outdated, repetitive, and boring approach to the plant world. This means that students rarely develop basic useful understandings about plants, or change their negative opinions about plant study. In addition to activities of interest to students, what seems to be missing is a framework which emphasizes the critical importance of plants in the environment, and which compares life functions of both plants and animals. Teachers have a wide range of resources available from which they might develop more imaginative and interesting lessons about plants. However, their lack of knowledge about the plant world, is a limiting factor.

In the review of literature on teaching, the importance of school culture, teacher professional development and implementation of innovations, the difficulties and complexities of the change process in the school context, as well as the idiosyncratic nature of change, are discussed. An understanding of the day-to-day social realities of a teacher's life in the classroom, the forces both inside and outside school that effect teachers, and the teachers beliefs and attitudes about knowledge are all necessary in any understanding of the teaching and learning process in schools.

CHAPTER 3

RESEARCH METHODOLOGY

Introduction

The research undertaken here is an evaluative study of an innovative teaching material, Wisconsin Fast Plants. This chapter contains an account of the plan for carrying out the study, including the research questions, research design, sample selection and treatment of the population under study, background of the participating teachers, instruments used to collect data, treatment of data, and limitations of the work.

Research Questions

This inquiry addresses the problem of finding ways to improve science education in America today. Specifically, it explores one practical approach through the introduction of an innovative biological teaching material, Wisconsin Fast Plants, in a group of middle and high school classrooms. The study seeks a solution to a highly practical problem: Can this new material, which appears to have great potential, actually work in the classroom?

Evaluation of the performance and value of the innovation is made by seeking answers to the following questions:

1. How well does the innovation, Wisconsin Fast Plants, perform in a variety of classroom conditions?
2. When provided with necessary equipment and supplies, how do the teachers in this particular sample use Wisconsin Fast Plants in their classrooms during the first year of the study? Which groups of students do they use the innovataion with? What changes, if any, occur in the level of use of the innovation during the second and third years?
3. What effects, if any, does the innovation have on the teaching of plant topics? Does the amount of time given to plant study change in any way? Are there changes in the plant topics included?
4. What changes, if any, occur in the kinds and amount of lab work which teachers using Wisconsin Fast Plants undertake? Do they do different activities, or are old activities repeated, substituting Wisconsin Fast Plants for other organisms?
5. What changes, if any, occur in student learning, as judged by their teachers, through the introduction of Wisconsin Fast Plants into the classroom?
6. What is the personal response of teachers and students to the innovation? Does introduction of the material into the classroom have any effects on teacher and student attitudes, feelings, and/or beliefs about

plants, plant study or science in general?

7. Do participating teachers feel that introducing Wisconsin Fast Plants into their classrooms helped them in any way to become better teachers, and/or to develop professionally?
8. What, if anything, about Wisconsin Fast Plants, do teachers share with others educators?

Sample Population Selection

The sample studied in this research was drawn from 112 middle and high school science teachers who had attended either of two summer residential National Science Foundation science education institutes held at Simmons College in Boston. Everyone in this group was invited to an introductory Fast Plant workshop presented by this researcher. The 32 teachers who attended the workshop were invited to pilot Fast Plants in their classrooms, and become part of this study. 22 teachers volunteered, and became the sample population in the study. All gave their informed consent to participate in the study by signing the Letter of Consent (see Appendix C).

The group was not a random sample of biology or life science teachers, nor was it meant to be a representative cross-section of all science teachers. Rather the group was intended to represent a particular sub-group of science teachers--those who are the most highly motivated, the most interested in growing professionally, and the most likely to try new ideas and innovations in the classroom. Thus, a willingness to try Wisconsin Fast Plants in the classroom during a single school year was the only criterion used in the selection process.

Background of Teacher Participants

The 22 participants were all classroom teachers at the beginning of the study (12 were male, 10 female). Nine taught in high schools, nine in middle schools, three in combination middle/high schools, and one in a K-8 school.

Teachers in the group worked a variety of schools; two in private schools, the rest in public schools. Seven schools were in large urban centers, seven in suburban communities, six in small towns, and two were in rural consolidated school districts. Space, equipment and resources varied widely. Some of the schools were lavishly equipped; others had limited space, equipment, and resources. Overall, middle schools were as well equipped as high schools.

At the beginning of the study, all the participants were teaching at least one class of life science, general science, or biology. Nine teachers were teaching only life science or biology courses, 11 also taught other science courses, and three taught other non-science subjects.

As a group, the teachers were highly experienced, having taught 15.4 years on the average. While one person had taught only two years, and three had taught 10 years or less, six had taught more than 20 years.

During the 3 year period of the study teachers taught biology, life science, general science, physical science, anatomy and physiology, marine biology/oceanography, ecology, earth science, chemistry, computers, math, reading and writing. 19 teachers (86%) had taught about plants before the study began; only three (two who taught 6th grade, and one who taught 6th and 7th grade) had not.

Table 3.1 Courses taught during 3 years of the study

	Number of Teachers		
Life Science	5	Independent Projects	1
Biology (college)	11	Physical Science	5
Biology (general)	3	Earth Science	4
Biology (honrs)	2	Chemistry	1
Biology II	1	General Science	3
Biology AP	3	Computers	1
Anatomy/physiology	2	Math	1
Marine biology/oceanography	3	Reading	2
Ecology/environmental science	4	Writing	1

The range of subjects taught in the past was even broader, and included (in addition to the subjects listed above) health, astronomy, physics, space science, and the standard elementary school subjects (math, language arts, social studies).

Table 3.2 Teaching experience of participants

Subject Taught (Present or Past)	%Teachers	#Teachers
Biology	64%	14
Specialized Biology Courses	68%	15
Advanced Biology (including AP)	(18%)	(4)
Ecology/Environmental Studies	(18%)	(4)
Marine Biology/Oceanography	(14%)	(3)
Research Projects/Lab Science	(9%)	(2)
Anatomy & Physiology	(5%)	(1)
Horticulture	(5%)	(1)
Physical Science (middle/high school)	36%	8
Life Science (middle school)	32%	7
Earth Science (middle/high school)	27%	6
General Science (grades 5,6,7,9)	27%	6
Chemistry	18%	4
All subjects (grades K, 3, 6)	14%	3
Computer Programming/Mathematics	14%	3
English	5%	1
Health	5%	1
Physics	5%	1
Astronomy	5%	1
Space Science	5%	1

One participant originally was an English teacher, another as a kindergarden teacher. A third had extensive experience in biological research and teaching at the university level; a fourth had been a chemist with a paint company for many years before starting a second career as a high school teacher. Three others had taught part-time at the college level sometime during their careers.

The group was well educated, although the details of their training varied. Three-quarters of the teachers held undergraduate degrees in various sciences, predominantly biology (46%). Of the other quarter, 14% had degrees in elementary education; the rest were spread over a variety of fields.

Table 3.3 Undergraduate majors of teacher participants

College Major	Middle	Middle/High	High School	Total
Biology	4 (18%)	3 (14%)	3 (14%)	10 (46%)
Chemistry	2 (9%)			2 (9%)
Biochemistry			1 (5%)	1 (5%)
Biology & Chemistry			1 (5%)	1 (5%)
Geology			1 (5%)	1 (5%)
Forest Management			1 (5%)	1 (5%)
Education	3 (14%)			3 (14%)
Philosophy/psychology			1 (5%)	1 (5%)
Bible/Christian Studies			1 (5%)	1 (5%)
English			1 (5%)	1 (5%)

17 (77%) of the teachers had Masters degrees at the beginning of the inquiry. Two teachers (9%) finished Masters degrees during the 3 year period of the study. All but two of the Masters degrees were in Education (61% in science education); the other two were in biology. One teacher had a PhD (in biology); another was enrolled in a Masters program; a third enrolled in a doctoral program (EdD) before the study was completed.

Table 3.4 Highest educational degree held by teacher participants

	Middle	Middle/High	High School	Total
PhD		1 (5%)		1 (5%)
MA/MAT/MEd	8 (36%)	2 (9%)	7 (32%)	17 (77%)
BA/BS/BEd	1 (5%)		3 (14%)	4 (18%)

Teachers varied in other ways as well. They had special biological interests--ecological topics were especially popular. Although all except one expressed some interest in plants, only six (27%) of the teachers listed plants as among their favorite biological interests.

Table 3.5 Aspects of biology teachers like most

Ecology, environmental issues, field biology, succession	14 (64%)
Plants	6 (27%)
Animals, invertebrates, animal behavior	4 (18%)
Anatomy & physiology	4 (18%)
Genetics	4 (18%)
Marine biology	2 (9%)
Molecular biology	2 (9%)
Cell biology	2 (9%)
Human body, psycho-biology	2 (9%)
Reproduction (plants and animals)	1 (5%)
Space biology	1 (5%)

According to the teachers, their students' interests were somewhat different than their own. Students shared an interest in ecology and the environment. Many thought that students liked anything related to humans. Student interest in plants was not thought to be strong.

Table 3.6 Teachers' opinions about the aspects of biology their students like most

Ecology, environmental issues, evolution	9 (41%)
Plants	5 (23%)
Animals, invertebrates	2 (9%)
Anatomy	5 (23%)
Genetics	6 (27%)
Marine biology	1 (5%)
Human biology, body	5 (23%)
Human reproduction	2 (9%)
Survey of plants and animals, diversity	2 (9%)

There was uniform agreement that students especially liked hands-on activities and labs.

Table 3.7 What students like to do most in science

Hands-on work, labs	22 (100%)
Cooperative group work, interactive work	4 (18%)
Microscope work	1 (5%)
Dissections	1 (5%)
Discussion, debate issues	1 (5%)

Many teachers found genetics and molecular biology especially difficult to teach, although none listed plants as one of the most difficult topics to teach.

Table 3.8 Biological topics teachers find most difficult to teach

Genetics	9 (41%)
Molecular biology, biochemistry	7 (32%)
Evolution	2 (9%)
Diversity	2 (9%)
Classification	2 (9%)
Adaptations	1 (5%)
Anatomy	1 (5%)
Cell biology	1 (5%)
Ecology	1 (5%)
Homeostasis	1 (5%)
Microbiology	1 (5%)

While many teachers (41%) found genetics especially difficult to teach, an even larger number (50%) listed it as among their favorite topics to teach. Plants were listed by only 4 (18%) of the teachers as one of their favorites.

Table 3.9 Topics teachers most like to teach

Genetics	11 (50%)
Ecology, enviromental science, field biology	10 (45%)
Plants	4 (18%)
Animals, animal behavior, invertebrates	5 (23%)
Anatomy & physiology	1 (5%)
Cell biology	1 (5%)
Classification	1 (5%)
Diversity	1 (5%)
Evolution	2 (9%)
Human body, reproduction, psycho-biology	4 (18%)
Life cycles	1 (5%)
Molecular biology	1 (5%)
Succession	1 (5%)

Many teachers (41%) felt that molecular biology and biochemistry was especially difficult for students. One teacher noted that all "theoretical processes" were hard for their students to understand.

Table 3.10 Most difficult parts of biology for students

Molecular biology, biochemistry	9 (41%)
Genetics	8 (36%)
Evolution	4 (18%)
Photosynthesis	2 (9%)
Adaptations	1 (5%)
Cellular biology	1 (5%)
Classification	1 (5%)
Diffusion, osmosis	1 (5%)
Homeostatic mechanisms	1 (5%)
Invertebrates	1 (5%)
Asexual vs. sexual reproduction	1 (5%)
Theoretical processes	1 (5%)

Two-thirds of the teachers (15 of the 22) had a science curriculum with specific topics that they were expected to cover (although several admitted they didn't complete everyting). Most (91%) used textbooks, and all but two liked the texts they were using. A substantial majority (73%) followed their texts closely, although less than half (41%) started at the beginning and moved toward the end of the text. Only about a quarter (23%) taught the entire book, or even attempted it. Three teachers (14%) used texts just for classroom reference, and two (9.%) didn't use them at all.

Table 3.11 Textbook use

	Yes	No	No Response
Use a textbook?	20 (91%)	2 (9%)	
Reference only?	3 (14%)		
Like the textbook?	18 (82%)	2 (18%)	2 (9%)
Follow text closely?	16 (73%)	4 (18%)	2 (9%)
Beginning to end?	9 (41%)	11 (50%)	2 (9%)
Teach entire book?	5 (23%)	15 (68%)	2 (9%)

Teachers used texts in many ways--for classroom reading and homework assignments, for lab exercises, and to a lesser degree, for tests. The single text most often mentioned was the traditional Modern Biology [Otto & Towle,1985], a book that has remained remarkably unchanged in more than a generation.

Table 3.12 Level and nature of textbook use

	Always	Often	Some	Rarely	Never
Read text	6(27%)	8(36%)	7(32%)	1(5%)	0
Textbook labs	3(14%)	5(23%)	9(41%)	3(14%)	2(9%)
Text homework	4(18%)	10(45%)	5(23%)	2(9%)	1(5%)
Textbook tests	5(23%)	3(14%)	6(27%)	2(9%)	6(27%)

Teachers left out different parts of their texts. Three left out something different each year, four left out sections on the human body, four didn't include ecology and environmental questions. Two did little with plants, two didn't deal with genetics, and single teachers left out animal behavior, diversity and evolution.

Textbooks were considered an important source for teaching ideas by slightly more than half (55%) of the teachers--more important than discussions with colleagues, but not nearly as useful as information gained in courses, teacher workshops, and conferences.

Table 3.13 Sources of teaching ideas

Courses, workshops, conferences	19 (86%)
Textbooks, teacher manuals, lab manuals	12 (55%)
Staff sharing, talking to other teachers	11 (50%)
Own knowledge and experience	9 (41%)
Professional publications	7 (32%)

The teacher participants were professionally active, involved in many different things in addition to piloting Fast Plants in their classrooms. 19 (86%) of the teachers were involved in trying something else that was "new" in their classroom; the other three were either enrolled in graduate degree programs, or were teaching elsewhere (at the college level or in extended in-service programs). During the 3 years the participants were very active professionally. They were involved in many different programs: thinking and problem solving skills, recombinent

DNA, local water ecology, Lego-Logo, or telecommunications. They were piloting new textbooks, supervising student teachers in their classrooms, writing for publishers and journals, presenting workshops to local, regional and national groups of educators, organizing and administering professional organizations, or working on their own scientific research.

All the participants attended professional workshops during the 3 years. Nearly all (95%) attended at least one local, regional, or national meeting of NSTA or NBAT. Over two-thirds of the group (68%) attended summer workshops (three as faculty). They participated in a wide variety of programs: Recombinant DNA (Cold Spring Harbor), Earth Watch Expeditions, Microcosmos (Boston University), a Chemical Education Workshop (University of Wisconsin), Geology and Oceanography Program (U. of Southern Maine), Grow Lab (National Gardening Association), Plant Systematics (Arnold Arboretum), Summer Genetics Institute (Massachusetts Department of Mental Health), NEED (National Energy Education Development) workshops, Oceanographic Summer Program (Woods Hole), Environmental Workshops (National Park Service, Cape Cod), and the Marine Biology Program (Key Largo, Florida).

Research Methodology

This inquiry is an evaluation research study about the usefulness of a new biological material, Wisconsin Fast Plants, and its effectiveness in science teaching. In the study, judgements about the material's value, merit and worth have been made from the perspective of a group of 22 teachers who used it in their classrooms over a 3 year period.

Given the nature of the problem (how well an innovative material, which appears to have great potential, actually works in the classroom), the methodology adopted here is not, and can't be, one of inductive hypothesis testing, of seeking a general Popper-Hempelian model and testing it simply in a quantitative manner. For this study, the inquiry centers not on theory, but on a set of open-ended questions.

This inquiry has been undertaken as an action research project, in which the research questions are not just posed by an external researcher, to be answered by teachers in their classrooms; but as a study in which teachers are encouraged to become researchers into their own practice. The role of the researcher in this sort of inquiry includes developing cooperative relationships with participating teachers, and assisting them to plan, monitor, and reflect on their teaching. Thus, rather than providing teachers with a set of prescriptive lessons plant or pre-determined curriculum, the project has been undertaken in an open-ended manner, with a wide degree of latitude offered to participants.

The research design includes a series of formative evaluations made at various points during the 3 years of the project, and a final summative evaluation. It draws on the work of Scriven [1967], and utilizes Guba and Lincoln's [1981] responsive evalution model, with its focus on the concerns and issues of the "stakeholders" (the teachers piloting the innovation). The study uses an "emergent design," in which many of the specifics of the research design evolve during the course of the study from insights gained as the researcher works alongside the participants.

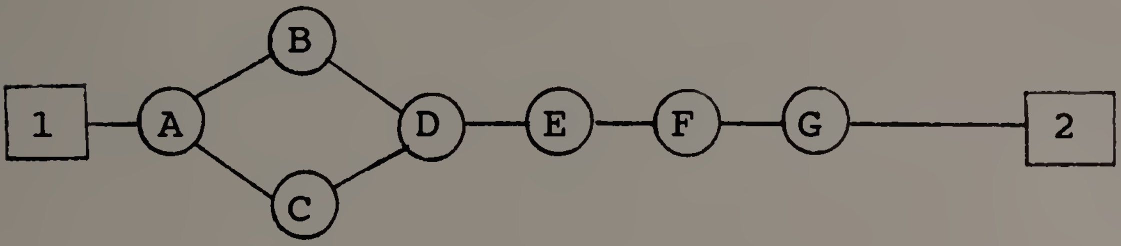
Unless otherwise indicated, the research findings, described in Chapter 4, are drawn from the final summative evaluation. Data for this evalution were collected with a standardized instrument meant to assess in a quantitative manner the impact that the innovation had on the thinking and teaching practice of the sample population over the entire 3 year period.

Organization of the Inquiry

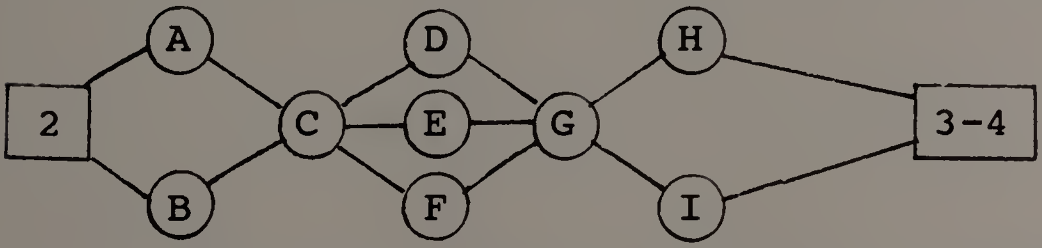
The research included 4 parts; 2 preliminary steps, and 2 later, overlapping steps, which continued through the 3 years of classroom trials. The plan for the study is shown below as a PERT (Planned Evaluation and Review

Technique) network. Details of each step are described following Figure 3.1.

Figure 3.1 PERT network for Fast Plants study



1. Preliminary work with Fast Plants (pre-trial year)
    - A. Introduction to Fast Plants
    - B. Initial review of literature
    - C. Growth trials with Fast Plants
    - D. Classroom pilot trial #1
    - E. Fast Plant workshop--University of Wisconsin
    - F. Permission to use Fast Plants for this study
    - G. Classroom pilot trial #2

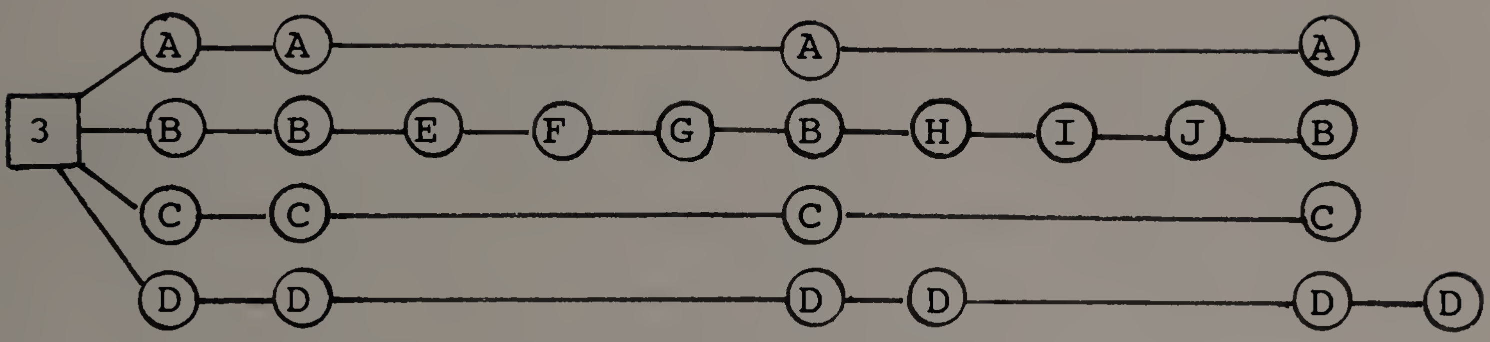


2. Recruiting sample population, planning and presenting Fast Plants Workshop #1 (pre-trial year--beginning of Year 1)
    - A. Securing funding for study
    - B. Defining target teacher population
    - C. Arranging date and place for workshop
    - D. Inviting target population to workshop
    - E. Planning workshop and initial teacher questionnaire
    - F. Purchasing equipment and supplies for participants in study
    - G. Presenting workshop
    - H. Providing volunteer participants with materials and supplies for study
    - I. Teachers complete initial questionnaire

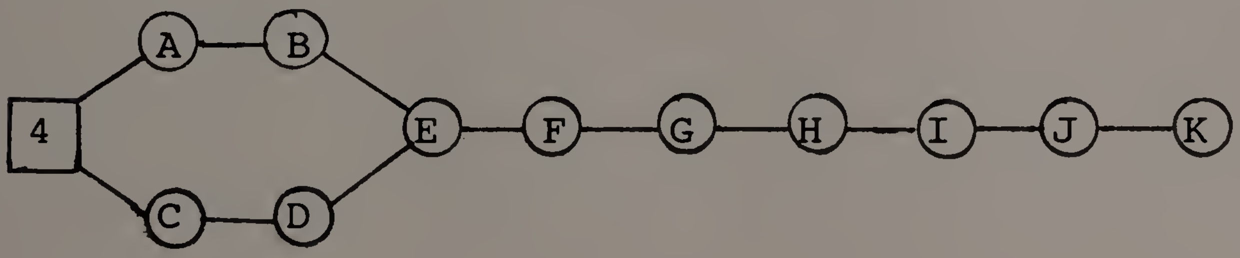
(Figure 3.1 continued on next page)

(Figure 3.1 continued)

Note: Steps 3 and 4 occur concurrently.



3. Communication with participants, support, and technical assistance (Year 1--Year 3)
   - A. Letter to participants
   - B. Informal telephone communication with participants
   - C. Technical assistance as requested by individual participants
   - D. Fast Plant Newsletter
   - E. Planning Workshop #2
   - F. Invitations to Workshop #2
   - G. Presenting Workshop #2
   - H. Planning Workshop #3
   - I. Invitations to Workshop #3
   - J. Workshop #3 presented



4. Monitoring Fast Plant Use, and Data Collection (Year 1--Year 3)
   - A. Setting up observational visits (by phone)
   - B. Classroom observation
   - C. Setting up Year 1 interview
   - D. Year 1 interviews
   - E. Planning Year 2 Questionnaire
   - F. Year 2 Questionnaire mailed to all participants
   - G. Follow-up phone calls to those who did not return questionnaire
   - H. Planning Year 3 Questionnaire
   - I. Participants complete Year 3 Questionnaire (by phone)
   - J. Planning Final Questionnaire
   - K. Participants complete Final Questionnaire (by phone)

Step 1: Preliminary Work with Fast Plants (January-June, pre-trial year)

A. Researcher introduced to Fast Plants at a workshop sponsored by the Massachusetts Department of Mental Health, and held at Simmons College, Boston.

B. Initial review of literature on Fast Plants, plant study, innovation, teacher professional development, innovation, and evaluation research.

C. Preliminary growth trials completed over a 4 month period (January-June) to gain first hand knowledge about Fast Plant care and maintenance, and to assess the innovation's potential for classroom use.

D. Classroom pilot trial #1. Fast Plants given to one high school teacher to try with students.

E. Attendance at a 4 day Fast Plant workshop at the University of Wisconsin, directed by Dr. Paul Williams.

F. Permission received from Dr. Williams to undertake study on Fast Plants.

G. Classroom pilot trial #2. Fast Plants used by the researcher in the classroom with a group of 40 high school students in a summer Upward Bound Program.

Step 2: Recruiting Sample Population, Planning and Presenting the Initial Fast Plants Workshop

A. Planning Workshop #1: Setting the date for the workshop, inviting the target group of teachers, planning the program, growing the Fast Plants for workshop use, and putting together the information packet for those attending the workshop.

B. Defining the Sample Population and Teacher Recruitment: Recruit methods and background of the sample population are described in an earlier section.

C. Funding: Materials and equipment for teacher participants was provided through an National Science Foundation grant to Simmons College, Boston. (See Appendix A for materials and equipment provided.)

D. Presenting Introductory Fast Plants Workshop (September, Year 1): Workshop presented to targeted teachers, who were introduced to Fast Plants through lecture and laboratory activities (see Appendix A). Teachers who volunteered to participate were provided with all necessary material and equipment at the end of the workshop.

Step 3: Communication and Participant Support (Year 1-3):

(Note: Step 3 and 4 occurred concurrently.)

A. Formal communication with teacher participants: Letters sent and phone calls made to all participants during the 3 years of the study.

Year 1: Two letters sent to all participants, and two phone calls (November and February) to check on progress, to schedule site visits and set up interview appointments.

Year 2: Two letters (including teacher questionnaire) sent. Phone calls made to those not returning questionnaire.

Year 3: One letter sent (including teacher questionnaire) and phone calls made to complete final summative questionnaire.

B. Informal communication with teacher participants: Technical assistance, advice and support provided by teacher request throughout the research period. Classroom visits, interviews, and two subsequent workshops also provided opportunities for informal communication between researcher and participants.

C. Fast Plant Newsletter: All participants received six Fast Plants newsletters from the Wisconsin Fast Plants Project at the University of

Wisconsin, containing information and other ways to utilize the material in the classroom.

D. Follow-up workshops:

1. Workshop #2 (Fall, Year 2): Participants invited to attend an informal half-day workshop to share experiences from the first year of use. 12 teachers attended.
2. Workshop #3 (Summer, Year 2): Participants invited to a 3 day Fast Plant workshop presented by Dr. Paul Williams held at Simmons College, and funded through a NSF grant to Dr. Williams and the University of Wisconsin. Nine teachers attended.

Step 4: Monitoring Fast Plant Use and Data Collection

During the 3 year period teacher use of Fast Plants and response to the innovation was monitored through written questionnaires, site visits, classroom observation, personal and telephone interviews, and informal conversations. Each specific instrument is described below.

Instrumentation and Data Collection

All data collection instruments were developed by the researcher. Each instrument was developed sequentially, based on the results of previous instruments. The information collected was used to make a series of formative evaluations during the study, and a final summative evaluation at the end of the research period.

The first instruments were open-ended, and the information gathered was generally qualitative. Each subsequent instrument developed was more structured and detailed, and data collected became more precise. Data collected in the final summative evaluation were primarily quantitative.

Each collection instrument is described below. (See Appendix B for actual collection instruments).

1. <u>Initial Teacher Questionnaire</u> (Autumn, Year 1): Used to gather information on each participant's educational background, teaching goals and experience, intended use of Fast Plants, and experience with plants in and out of the classroom.
2. <u>Classroom Observation Schedule</u> (Year 1): A guide for classroom observations made during the first year of the study. Used to get a general feel for individual classrooms teaching style and methodology, student response to the innovation, and ways in which Fast Plants were being used.
3. <u>Student Questionnaire</u> (Year 1): Used to gather data on student response to Fast Plants during the first year of the study, to compare student and teacher response, and to check the veracity of teacher statements. Students completed questionnaire immediately after having completed work with Fast Plants.

4. <u>Interview Format</u> (Year 1): Used as a guide in an open-ended semi-structured interview with all teachers about their use of Fast Plants during the first year. Interviews arranged at the convenience of each teacher, and were taped by the researcher, with permission of participants, for later reference.

5. <u>Year 2 Questionnaire</u> (Fall, Year 2): Used to collect data on teacher response to Fast Plants after first year of use, and intended uses, if any, during the second year.

6. <u>Year 3 Questionnaire</u> (Fall, Year 3): Used to collect data on use and response to Fast Plants during the second year, and intended uses, if any, during the third year.

7. <u>Final Summative Questionnaire</u> (Spring, Year 3): Used to collect data from all participants on their use and response to Fast Plants during all 3 years of the study. Data collected by telephone.

8. <u>Telephone Conversations and Correspondence</u>: Notes were kept of telephone conversations with paraticipants during during the 3 years. Correspondence to and from individual teachers kept for later reference.

Data Analysis

Data collected from each instrument were analyzed, coded where possible, and results were used in developing each subsequent instrument. The data collected using the various instruments were used to cumulatively answer all of the research questions, in a continuing cycle of refining the questions and quantifying the answers.

Limitations

There are three necessary conditions for assuming a causal relationship between two variables. The first is a temporal antecedent, in which the cause must precede the effect in time. The second is that the treatments must co-vary with the effects. If cause and effect are not related, one could not cause the other. The third necessary condition is that there must be no other plausible explanation of the effect other than the cause. In any research there are threats to the validity of the findings, based on the reliability for distinguishing and describing, measuring, and separating cause and effect. In this study there are several threats to the validity of the research findings that must be noted.

The first two conditions are easily met. First, there is a clear temporal antecedent of cause to effect; and second (as will be documented in chapter 4), a co-variance between treatment and effect.

There are potential problems in meeting the third condition. Because the research took place in field settings, rather than in the laboratory, it is more difficult to rule out all other variables that might alternatively explain the relationship between the cause and the effect. An attempt was made to do this by gathering data on all the other new programs, curricula, pedagogical ideas and the like that participants were involved in during the three years of the study. No other specific program in which participants were involved, however, seemed to directly affect the results of the study. Information on these programs can be found in an earlier section in this chapter on the background of teacher participants.

One potential threat to the internal validity of the study may be the fact that, except for the single student questionnaire, all data were collected from the teachers' perspective. However, rather than evaluating success of the innovation in terms of student learning or from some other external variable, the inquiry was designed to assess the material's usefulness from the the viewpoint of the teacher users.

It is also possible that participants misreported their uses of Fast Plants, or distorted their own response to the innovation. Attempts were made to correct or at least illuminate this bias by making classroom observations, by the use of a student questionnaires during the first year of the study, and by asking teachers the same questions at different times, or the same question worded differently in a single questionnaire. Although not definitive, data collected in these ways indicated strong uniformity. Continued use of Fast Plants after the first year was entirely by individual choice, and where it occurred, substantiated teachers' positive response to the material.

Another potential threat, a high attrition rate of the sample over time, did not occur. Because of the nature of the sample population, the time frame of the study, and the wide range of ways the material was used in classrooms, it is unlikely that the effects were have been attributed to differences in teachers, schools, or students.

In terms of external validity, there may be limitations to the generalizations that can be made, since the sample population was a group of volunteers, rather than a randomly selected group. However, generalizations made from the study are intended to be primarily applicable to the particular "target instance" [Cook and Campbell, 1976] under study--those highly professional and dedicated teachers wishing to improve their performance in the classroom. The target group itself is probably large, judging from the numbers attending regional and national meetings of science teachers.

This research can be viewed as a first step in assessing the usefulness and effectiveness of the innovation. If Fast Plants prove not to be an effective and useful teaching tool for the sample population under study, it is unlikely that the innovation will be any more successful in a broader cross section of science teachers. However, generalizations made in this study may still be valid, although possibly less reliable, in a more general population of teachers.

CHAPTER 4

FINDINGS

Introduction

The results of this research on the usefulness and effectiveness of Fast Plants in 22 middle and high school classrooms during a three year period are organized in eight sections: 1) the technical performance of the innovative material in the classroom, 2) uses of Fast Plants, 3) time spent on plant study and plant topics covered, 4) hands-on activities and lab work using living plant material (including Fast Plants), 5) student learning (from the teachers' perspective), 6) teacher and student feelings about plants and attitudes toward plant study, 7) teachers' opinions about their own professional development, and 8) teacher dissemination of information about Fast Plants. Details can be found in the sections below.

Technical Performance of Fast Plants

Fast Plants performed well in the classrooms over the three year period. The plant stock was hardy and uniform. Teachers found the plant maintenance system easy to use, and all agreed that Fast Plants were easy to grow. Nearly everyone (91%) agreed that the plants were easy to care for, and two-thirds (66%) thought that Fast Plants were easier to maintain than other organisms they had used in the classroom. Most teachers thought that Fast Plants were an inexpensive teaching material (although a single teacher disagreed). No significant differences were noted between teachers who had extensive experience with plants and those who had little or none.

Table 4.1 Performance of Fast Plants in the classroom

Fast Plants are:	Agree Strongly	Agree		Disagree	No Opinion
Easy to grow	16(76%)	5(24%)			
Easy to care for	13(62%)	6(29%)	2(10%)		
Easier to maintain than other organisms	10(48%)	4(19%)	5(24%)	1(5%)	1(5%)
Are inexpensive	7(33%)	8(38%)	3(14%)		2(10%)

At the beginning of the project more than half (59%) of the teachers anticipated no major problems with the innovation, and expressed confidence in their abilities to handle any problems that might arise. The rest expressed a variety of concerns. Would the plants actually grow? Would they produce seed? Would the watering system work, especially during vacations? Were their classrooms too cold, too warm, or too drafty? Could they find space in their classrooms for Fast Plants? Could they find time in already overloaded schedules?

In interviews at the end of the first year, every teacher, regardless of their own particular experience, said that Fast Plants had been successful and useful. Everyone was impressed with the reliability of the material. One teacher was astonished that "each square (in the four celled plant pot) had a plant in it and each student had a plant." Another noted the uniformity of growth and the accuracy of the timetable which "dazzled" both students and teacher. "Right on target," commented a third, while a fourth called the plants "just like clocks."

The high germination and plant viability rates were impressive to teachers. Several noted germination rates of nearly 100%; many (12) commented on the germination of the plants. Others (4) were impressed with the ease of transplanting and the ability of the plant to withstand even the roughest treatment by students. High germination rates, and ease in transplanting, are not always typical with other kinds of plants.

The system for growing and maintaining the plants also worked. Constant 24-hour lighting meant there was no need for timers or remembering to turn the lights on and off. All the teachers were able to find a large enough space in their classrooms for the four-foot long light bank, (although one teacher had to hang the lights under a low cupboard, where the plants grew well, in spite of touching the light bulbs).

Table 4.2 Methods used to set up lights for Fast Plants

hung on existing metal plant stands	6
teacher or student built light frames	4
on top of boxes or piles of books	8
hung in bookcases	2
hung under cupboards	1
hung from the ceiling	1

In spite of a high rate of success during the first year, there still were problems, most of them minor. At the end of that year teachers noted a number of problems, listed below.

Table 4.3 Problems with Fast Plants, year 1

Germination	1
Seeds plants incorrectly	5
Plant death	7
Low seed production	3
Water problems	9
Lights	6
Space in classroom	3
Time in schedule	5

Although the lighting system worked well for most, several teachers had some difficulties at first. One teacher set the lights up incorrectly, creating three banks of lights with two bulbs, rather than a single bank with six bulbs. The teacher seemed unaware that the plants were leggy, or the life cycle lengthened. Setting up the lights was difficult for some of the women. Two got help from colleagues or husbands; two others were sure they couldn't have done it if the lights had not already been assembled on a frame.

Finding time to set up the lights was problem for one teacher. Two teachers, who taught in an urban school system which shut off the electricity after school, had to move their plants at the end of each day to locations outside their own classrooms which had emergency 24 hour circuits.

A few also had problems with the seed stock. One teacher had very low rates of germination with the original package of seeds. Replacement seeds germinated at a high rate, and poor germination was never a problem again. Five teachers mentioned students who had planted the seeds incorrectly, putting seeds at the bottom on the pot, fertilizer at the top, which resulted in little or no germination.

Plant death was a major problem in only one case, when a furnace the failed over winter vacation killed all the plants, ending work with Fast Plants. Three other teachers had low seed production, but in each case the explanation seemed to be inadequate pollination by students.

Water is a critical factor for Fast Plants, and in the first year nine (41%) of the teachers had water related problems, including water reservoirs that went dry over long weekends, plants that were pushed off the back of the reservoir, and occasional wicks that jammed. None of the problems was severe enough to end the project.

Five teachers had difficulty finding an uninterrupted 40 day time period in which to use Fast Plants. Not only school holidays, but testing, field trips, special school programs, and other constraints in schedules had to be carefully considered.

During the second year, a new material for wicks and water mats was substituted by the commercial vendor of Fast Plants for a different produced previously available from the University of Wisconsin. All the teachers (5) who ordered water mats from the vendor during the second or third years had problems. For most the problem was simply a nuisance, solved by top watering the plants during the entire cycle, or by replacing the matting with other sorts of absorbent materials (Handi-wipes, paper towels, or Pellon). But for one teacher, growing a large number of plants for a professional workshop, it was a catastrophe.

By the end of the third year, even those things that had seemed to be problems at the beginning of the project had disappeared, and two-thirds of the teachers said they remembered no real problems during the entire three years. The others remembered various difficulties, most of which in hindsight seemed minor.

Table 4.4 Problems teachers encountered over the 3 years

	Major Problem	Minor Problem	No Problem
	14 (67%)		
Death of plants		1 (5%)	3 (14%)
Seed germination		1 (5%)	3 (14%)
Seed viability			3 (14%)
Water matting, wicks		1 (5%)	8 (38%)
Lights			3 (14%)
Plants knocked over			2 (10%)
Styrofoam pots			2 (10%)

Fast Plant Use in the Classroom

During the first year, there were 22 teachers in the study, all of whom used Fast Plants with at least one group of students. In the second and third years of the study there were 19 classroom teachers (one teacher left the profession at the end of the first year, and two teachers took sabbaticals each year). Although one teacher on sabbatical during the second year did not return to full time teaching the third year (for health reasons), she but did continue to use Fast Plants in a local elementary school as a volunteer teacher's aide (and was included in the study as a teacher using Fast Plants). Use remained high during the second and third years (14 teachers in year 2, 15 in year 3). The level of use is high whether shown as a percentage of the original group, (64% in year 2, 68%

in year 3) or as a percentage of those in the classroom (74% in year 2, 78% in year 3).

Half (50%) of the original group (without correcting for those who were not teaching in either the second or third years) used Fast Plants for all 3 years of the study, while 77% used them for two out of the 3 years. There were a number of reasons why teachers did not continue to use Fast Plants, including lack of time in their schedule, curricula that no longer included plants, lack of funds to replace materials.

Table 4.5 Fast Plant use over 3 years

	Year 1	Year 2	Year 3
# Participants:	22	21	21*
# Classroom Teachers:	22	19	19*
# using Fast Plants:			
As % of original participants (22)	22(100%)	14(64%)	15(68%)*
As % of classroom teachers	22(100%)	14(74%)	15(78%)*
Reasons for non-use:			
Left Teaching		1	1*
Sabbatical		2	2
Not in curriculum		2	2
Lack of time		2	1
Lack of funds to resupply		1	1
Restart after non-use			3
Reasons for restart			
Post-sabbatical		2*	
More time available		1	
Percentage of users for 3 years:			11 (50%)
Percentage of users for at least 2 years:			17 (77%)*

<u>NOTE</u> * includes one teacher who took sabbatical in year 2, left teaching in year 3 but taught Fast Plants as a volunteer in an elementary school

At the end of the third year, 15 (71%) of the teachers said they definitely planned to use Fast Plants during the fourth year, and 4 (19%) hoped to. These categories included two who had not used Fast Plants during the second or third years, and two who were returning from sabbaticals. Plants were still not part of two 6th grade teachers' curricula.

Table 4.6 Intentions for use in the fourth year

		Number of teachers
Definitely intend to use year 4		15 (71%)
Intend to use same amount		11 (52%)
Hope to increase amount		4 (19%)
Unsure		4 (19%)
Intend to use in same way		7 (33%)
Different/additional ways		8 (38%)
Hope to use in year 4		4 (19%)
if still teaching	(2)	
if funds available	(1)	
if time available	(1)	
Will not use in year 4		2 (10%)

All the high school teachers taught biology classes which were divided by level (basic, general, honors). A few teachers also taught second year or AP (advanced placement) biology. The middle school teachers taught heterogeneously grouped classes. Thus high school teachers not only had a choice of the number of classes, but also the level, in which to use Fast Plants.

During the first year, three middle school teachers used Fast Plants in all their classes. One high school teacher used them with all classes (of various levels).

High school teachers used Fast Plants most frequently with college level classes, although they also used them in honors and basic level classes.

Table 4.7 Courses in which Fast Plants used

	Year 1	Year 2	Year 3
Fast Plants Course Use:			
Grade 6 Science	3	1	0
Grade 7 Science/Life Science	5	3	2
Grade 8 Life Science	2	0	1
Grade 8 Earth Science	1	1	1
Grade 9 Science (basic)	2	1	1
Grade 9-10 Biology (basic)	2	2	2
Grade 9-10 Biology (college)	5	5	4
Grade 9-10 Biology (honors)	1	1	0
Biology II/AP	2	1	1
Independent Research	1	0	0

The number of classes in which teachers used Fast Plants increased during the three year period. 14% of the teachers used the material with three or more classes in the first year. The percentage rose slightly in the second year to 16%, and to 27% in the third year. It is interesting to note that one teacher (out of nine in the group who taught earth or physical science in addition to biology or life science) used Fast Plants in a unit on soil during all three years.

Table 4.8 Number of classes using Fast Plants

	Year 1	Year 2	Year 3
Total # teachers	22	19	19
# using Fast Plants in:			
0 classes	0	6 (32%)	4 (21%)
1 class	11 (50%)	4 (21%)	6 (32%)
2 classes	8 (36%)	6 (32%)	4 (21%)
3 classes	1 (5%)	1 (5%)	2 (11%)
4 classes	0	0	1 (5%)
5 classes	2 (9%)	2 (11%)	2 (11%)

Results show a gradual increase in use over the three year period, in terms of the number of topics Fast Plants were used for, in multiple rather than single use in individual classes, and in use with additional classes. Informal teacher comments throughout the study also indicate a continuing refinement and improvement in specific activities with repeated use.

Table 4.9 Teacher use of Fast Plants over 3 years

Fast Plant Use:	Number of Teachers
No change in use	1
Use by additional classes	5
Used for additional topics	11
Used with additional goals	12

Most teachers (91%) found it was very easy to fit Fast Plants into their existing program, while an additional 5% found it quite easy. Only one teacher (5%) said it was difficult (because plants were not part of the curriculum). A substantial proportion (67%) found that increase in workload was slight. One noted, "If anything, Fast Plants decreased the workload." Another said, "Fast Plants didn't increase the workload much. The kids took care of it."

Teachers also agreed that Fast Plants were useful for students of different abilities (92%), and of different ages (76%). Nearly all (95%) thought that Fast Plants were accessible, in the sense that previous successful learning (about science, plants, or anything else) was not required.

Table 4.10 Usefulnesss of Fast Plants

Fast Plants:	Strong Agreement	Agreement	Neutral/ No Opinion
Are easy to fit into my curriculum	18 (86%)	2 (10%)	*
Are useful for students of different ages	13 (62%)	3 (14%)	5 (24%)
Are useful for students of different abilities	17 (81%)	2 (10%)	2 (10%)
Are accessible--previous learning not necessary	10 (52%)	9 (43%)	1 (5%)

* -- One teacher disagreed

During the three years, Fast Plants were used most commonly for studying plant growth and development. Teachers felt that Fast Plants gave students the opportunity to observe the entire life cycle of a plant, not usually possible because of the long life cycle of most plants.

At the end of the third year nearly all (93%) of the teachers were using Fast Plants in the study of plant life cycles, and growth and development. This was the only use made by three teachers. Many used the material in many other ways, including plant anatomy, plant reproduction, the effects of varying environmental conditions on plants (light, fertilizer, acid rain, etc.), and genetics. Individual teachers also used them in studies on plant/insect relationships, radiation studies, plant breeding exeriments, and to demonstrate pollen germination.

Several teachers used the organism primarily as a research tool. Their goal was to help students learn how to do scientific investigations by actually doing them. Some students also used Fast Plants for science fair and independent research projects.

Table 4.11 Major classroom uses of Fast Plants

	Year 1	Year 2	Year 3
Growth & development, life cycle	18 (82%)	12 (92%)	13 (93%)
Plant anatomy	7 (32%)	7 (54%)	8 (57%)
Plant reproduction	5 (23%)	7 (54%)	7 (50%)
Experimental method	6 (27%)	6 (46%)	7 (50%)
Independent research	4 (18%)	3 (23%)	4 (29%)
Techniques for growing plants	3 (14%)	4 (31%)	4 (29%)
Genetics/population genetics	2 (10%)	5 (39%)	4 (29%)
Effects of plant hormones	0	2 (15%)	3 (21%)
Effects of chemicals	0	0	3 (21%)
Effects of fertilizer	2 (9%)	2 (15%)	2 (14%)
Effects of gravity	0	1 (8%)	2 (14%)
Effects of light	2 (9%)	0	2 (14%)
Effects of acid rain	2 (9%)	3 (23%)	2 (14%)

Teaching about Plants

During the three years of the study a substantial proportion (86%) of the teachers increased the time spent on plant study with their classes. Just over half (52%)

said there had been an increase in the number of plant topics covered in the classroom, and nearly all of the teachers (95%) thought that the number of lessons on plant topics they personally developed increased.

Table 4.12 Change in time spent on plant study

Since using Fast Plants:	Increased Greatly	Increased	No Change
Time spent/plant study	9 (43%)	9 (43%)	3 (14%)
# lessons/plant topics	4 (19%)	16 (76%)	1 (5%)
# plant topics covered	7 (33%)	4 (19%)	10 (48%)

Overall teachers thought the time spent on plant study increased by about a third (34%) since using Fast Plants (with a range of increase of 0%-100%). The time teachers spent on plant topics ranged from several weeks to more than a quarter of the school year.

Table 4.13 Increase in time spent teaching about plants

Percentage of Increase	Number of Teachers
100%	2
83%	2
75%	1
50%	3
33%	1
20%	2
15%	1
10%	2
5%	4
0%	3

Nearly half (43%) thought they spent more time on plants than others in their schools. Almost three quarters

(72%) of the teachers said they intended to continue to spend the same amount of time on plants, while (28%) intended to increase the time they spent on plants in the future.

Table 4.14 Amount of time spent teaching about plants

<u>Amount taught about plants</u>	
More than others in school	9 (43%)
Same	6 (29%)
Less	1 (5%)
No one else teaches plants	2 (9%)
Don't know	3 (14%)
<u>In future plan to teach about plants</u>	
More	5 (28%)
Same	13 (72%)

Most teachers also felt that their students, no matter what their age or level, had limited knowledge about plants. There was considerable disagreement, however, about whether or not their students were less interested in plants than in other topics. At the same time they felt teacher interest in plants was strong, and that plants were an important topic to teach.

Table 4.15 Knowledge and interest in plant topics

	Strongly Agree	Agree	---	Disagree	Strongly Disagree
Student plant knowledge limited	17(81%)	2(10%)	1(5%)	1(5%)	0
Student interest in plants less than other topics	8(38%)	4(19%)	6(29%)	3(14%)	0
Teacher interest in plants less than other topics	0	0	1(5%)	5(24%)	15(71%)
Plants less important than other topics	0	0	1(5%)	2(10%)	18(86%)

The teachers also thought that there was an imbalance between the attention given to animals compared to plants in school science.

Table 4.16 Imbalance: teaching about plants and animals

Imbalance between plant/animal teaching	
Yes, great deal	10 (50%)
Yes, some	5 (25%)
No	4 (20%)
No opinion	1 (5%)

The teachers covered a wide array of plant concepts in their classes. The emphasis was on seed plants; 65% of the teachers spent little or no time on lower plants. The greatest amount of time was spent on reproduction (including flower structure), photosynthsis, respiration and life cycle, with considerably less emphasis on other topics (tropisms, germination, nutrition, transpiration, insect plant relationships, world food production, seeds, roots and stems, plant ecology).

Table 4.17 Time spent on various plant topics

Topic:	Very Large	Large	Some	Little	None
Classification	2(10%)	5(25%)	6(30%)	4(20%)	3 (15%)
Lower Plants		1(5%)	3(15%)	13(65%)	
Seed Plants	9(45%)	7(35%)	4(20%)		
Seed Structure	3(15%)	3(15%)	10(50%)	4(20%)	
Root Structure	2(10%)	4(20%)	9(45%	4(20%)	
Stem Structure	4(20%)	2(10%)	9(45%)	5(25%)	
Leaf Structure	4(20%)	5(25%)	8(40%)	3(15%)	
Flower Structure	7(35%)	7(35%)	5(25%)	1(5%)	
Growth & Development, Life Cycle	5(25%)	5(25%)	8(40%)	2(10%)	
Germination	2(10%)	3(15%)	8(40%)	7(35%)	
Plant Nutrition	4(20%)	2(10%)	3(15%)	10(50%)	1(5%)
Plant Tropisms	1(5%)	2(10%)	9(45%)	7(35%)	1(5%)
Photosynthesis	7(35%)	7(35%)	4(20%)	2(10%)	
Respiration	4(20%)	7(35%)	7(35%)	2(10%)	
Transpiration	2(10%)	5(25%)	10(50%)	5(25%)	
Reproduction	8(40%)	5(25%)	6(30%)	1(5%)	
Genetics	3(15%)	5(25%)	6(30%)	6(30%)	
World Use/Plants	2(10%)	6(30%)	6(30%)	5(25%)	1(5%)
Food Production	3(15%)	1(5%)	7(35%)	6(30%)	1(5%)
Plant Ecology	4(20%)	5(25%)	5(25%)	6(30%)	
CO^2 & O^2 cycles	1(5%)	7(35%)	4(20%)	8(40%)	
Insect/Plant Relationships	5(25%)	8(40%)	5(25%)	2(10%)	

Most teachers (76%) agreed that Fast Plants helped them teach about plants more efficiently. A substantial proportion also felt that they could be used in many different ways (90%), and that they were useful for many different topics (86%). Fewer voiced strong agreement that using Fast Plants encouraged the teaching of particular topics in greater depth (76%).

Table 4.18 Fast Plant use & teaching about plants

Fast Plants:	Strongly Agree	Agree	Neutral/ No opinion
Encouragement to increase amount of time spent on plants	9(43%)	7(33%)	5(24%)
Helped me teach plants more efficiently	11(52%)	6(24%)	4(19%)
Useful for many different topics	13(62%)	6(24%)	2(10%)
Allow teaching of particular topics in greater depth	7(33%)	9(43%)	5(24%)
Can be used over again in many different ways	15(71%)	4(19%)	2(10%)

Doing Science in the Classroom

Teachers thought their students spent about 40% of their time, on the average, doing "hands-on" or lab activities. The figure was slightly higher for middle school teachers (44%), and slightly lower for high school teachers (37%). The range of responses was between 25% and 90%. Some teachers did more lab work with the less able students, less with the more capable students. Others did just the opposite.

There was universal agreement among the teachers that students liked the interactive parts of science class the most. Teachers spoke of students liking to "do things," "be active," do "hands-on" work, or lab activities. Student responses indicated the same preference.

It was often difficult for teachers to do as many labs and hands-on activities as they would have liked. Inadequate funding was a problem for many of the teachers; sometimes it was a major limitation. Some teachers had inadequate lab facilities, and many wished they had more time to preparing labs. On the other hand, there was agreement that there were many things that could be done with plants in the classroom, especially with Fast Plants.

Table 4.19 Limiting factors to Fast Plant use

	Not restrictive			Very restrictive	
	1	2	3	4	5
Inadequate funding of lab materials	7(35%)	1(5%)	4(20%)	4(20%)	4(20%)
Inadequate lab facilities	9(45%)	2(10%)	4(20%)	3(15%)	2(10%)
Little time for lab prep	5(25%)	2(10%)	10(50%)	1(5%)	2(10%)
Little can do with plants in class	16(80%)	3(15%)	1(5%)		

Science was usually done in the classroom setting; it was rare for students to do science outside. When asked how frequently students did science outdoors, most (62%) responded "rarely."

Table 4.20 Amount of science done outdoors

Science done outdoors:	# Teachers
Very frequently	0
Frequently	3 (14%)
Occasionally	5 (24%)
Rarely	13 (62%)

Teachers used a wide variety of plant materials for hands-on activities and lab work. The most common seeds were bean and corn, but carrots, radishes, pumpkin, alfalfa, and peanuts were also used. The most common plants used were geraniums, wandering Jew, spider plants and ferns, but they sometimes used more exotic plants such as orchids or carnivorous plants. Frequently teachers used whatever plant materials they could get their hands on, sometimes from their own backyards or the school grounds. A few sometimes got flowers too old to sell from florists and grocers.

More than two-thirds of the teachers had plants growing in their classrooms. Lack of natural light was a common problem. There were greenhouses in three schools; only one was used, and not by the teacher who was doing Fast Plants.

Table 4.21 Number of plants growing in classrooms

	Number of Teachers
Large number of plants	5 (23%)
Some plants	7 (32%)
A few plants	3 (14%)
No plants	7 (32%)

Teachers frequently got their ideas for hands-on activities from lab manuals accompanying their textbooks. Especially popular labs were on chromatography, photosynthesis, transpiration, and plant anatomy.

Table 4.22 Teacher use of textbook lab activities

Lab activities from texts used:	
Always	3 (14%)
Often	5 (24%)
Sometimes	11 (52%)
Rarely	2 (10%)

Teachers found some activities, especially those on photosynthesis, often didn't work well. A few also complained that it was difficult the have particular plants in the right stage of development when needed. Many noted that Fast Plants were invaluable in this respect because of the reliability of their life cycle.

In most classrooms, activities tended to demonstrate concepts or structures taught previously, rather than encouraging students to find things out for themselves. Teachers rarely taught students the rudiments of plant care. Outdoor gardening was done by only one middle school teacher, while another middle school teacher included indoor gardening projects. Only two teachers spent any time in helping students to learn about the plants commonly found near their schools, although a substantial proportion (82%) spent at least a little time in the classroom on plant classification. Several thought classification was extremely boring.

Nearly two-thirds (62%) of the teachers said they especially like using plants for lab work, noting that plants were easy to use, practical, predictible, and had "no problems." Furthermore they thought plants were easier to care for than animals in the classroom, and were easy because they "don't move"--one of the characteristics that made animals so interesting to students.

Many in the group were considering expanding their use of plants for hands-on activities because of ethical questions about animal use in the classroom. A few believed that plants soon would be one of the few kinds of organisms they would be able to use for lab work, because, as one teacher put it, "there are no societies for the prevention of cruelty to plants." Two others were trying to do more labs with plants, because they questioned the value of spending so much time on animal disssection at the middle and high school level. To one teacher, an "animal person" (with many years' experience as a researcher), but no botanical background, plants, and especially Fast Plants were appealing, because they offered a way to continue to do research while teaching high school.

The most common activity that students did with Fast Plants was simply to grow the plants, and observe its life cycle. This was done by 19 of the original 22 teachers. Students usually started with a single seed, and eventually harvesting the seeds at the end of the cycle. In addition to recording their observation, students often measured, and sometimes graphed their results.

Half of the teachers (11) had students do some sort of long term experiment with the plants. Investigations that explored the effects of varying amounts of fertilizer, acid rain, salt, or radiation were popular. In other classrooms students explored the effects of growth hormones (indoleacetic acid, gibberillic acid, abscisic acid), and different wave lengths of light on Fast Plants.

There was wide variation in the level of student work. Sometimes it was of high quality and very accurate; other times it was poorly written, or non-existent. Sometimes student results were incorrect or inconsistent. Some teachers commented that their students found measuring and recording results tedious; others were astonished at their students continued interest, and the care they took in collecting data.

Usually everyone in a class did the same experiment, often working in cooperative groups. In a few classrooms, Fast Plants were used for science fair projects. Two students (in different schools) worked on long term independent projects during their own free time, motivated solely by their own interest. One of them was a non-reading special needs student who had wondered what would happen if Fast Plants were grown under different colored light. He spent the whole year working on the problem, designing and building a series of cellophane covered boxes to try to answer his question.

During the first year, two teachers (one middle school and one high school) used Fast Plants as a research tool, and focused their entire attention on helping students learn how to do experiments. In the middle school, the class voted on a single experiment, which they designed and completed as a group. In the high school classroom students worked in pairs on a 5-6 week independent research project, not only designing and doing their own experiments, but also writing a scientific paper describing their work. The level of student work improved considerably over the 3 years, as the teachers ability to help their students do investigative science increased. During the third year, the high school teacher had college classes, as well as honors classes doing they own original research projects. Two other teachers were beginning to use Fast Plants in this way, and five others intended to move in that direction during the fourth year.

Throughout the study there was much talk, especially by high school teachers, about the potential of Fast Plants for genetic studies. Nine teachers talked about it in interviews at the end of the first year, and of their intentions to use Fast Plants in this way. Several mentioned how much they disliked fruit flies, and how difficult they were to work with in the classroom.

However, for all the talk, few actually ever used Fast Plants in this way. During the first year, two teachers tried to do population studies, using only wild type seed, without great success. While seven teachers said they planned to use Fast Plants for genetics during the second year, only three (all high school teachers) actually carried out genetic studies of any sort. By the end of the third year, only four teachers (three high school and one middle school) had used any of the mutant stocks. Five more (two high school and three middle school) said they hoped to do so in the future. But four high school teachers, who had expressed interest in using Fast Plants for the study of genetics during the first year, did not mention it as a specific intention for future use at the end of the third year.

Table 4.23 Genetic Studies with Fast Plants

	Number of Teachers
Population genetics using wild type stock	2
Mendelian genetic studies using mutant stock	3
Hoped to use Fast Plants for genetics (end of first year)	9
Intend to use Fast Plants for genetics in year 2 (beginning of second year)	7
Intend to use Fast Plants for genetics in year 4 (end of third year)	5
Use of Fast Plants for genetics (second year)	4

All the teachers agreed that Fast Plants gave their students a chance to collect, record, and analyze their own data. Nearly as many thought that Fast Plants gave students the opportunity to raise their own questions and answer them. Teachers also agreed that Fast Plants helped their students work like real scientists in the classroom.

Table 4.24 Doing science with Fast Plants

Fast Plants:	Strong Agreement	Agreement	No Change	No Opinion
Give students a chance to collect & analyze their own data	18(86%)	3(14%)	0	0
Give students the chance to raise own questions and answer them	8(38%)	10(48%)	0	3(14%)
Give students a chance to work like real scientists	14(67%)	4(19%)	3(14%)	0

All teachers said that Fast Plants gave their students a chance to use science process skills in the classroom. The practice that they got, however, was uneven, depending on the activity itself, as well as the emphasis that teachers put on helping students to develop and refine those skills.

When working with Fast Plants in the classroom, students used observational skills the most, planning and critical reflection skills the least. While 72% of the teachers agreed that with Fast Plants their students had a chance to raise their own questions "very often" or "often," only 33% said that their students were "often" involved in planning experiments, and only 14% said that this happened "very often."

Table 4.25 Levels of use of science process skills

Skill:	Very Often	Often	Some-times	Rarely	Never
Raising Questions	5(24%)	10(48%)	3(14%)	3(14%)	
Hypothesizing	5(24%)	9(43%)	4(19%)	2(10%)	1(5%)
Planning	3(14%)	7(33%)	4(19%)	1(5%)	6(29%)
Observation	20(95%)	1(5%)			
Measuring	18(86%)	2(10%)	1(5%)		
Recording	15(71%)	6(29%)			
Graphing results	6 29%)	5(24%)	5(24%)	2(10%)	3(14%)
Interpreting	6(29%)	9(43%)	4(19%)	1(5%)	1(5%)
Critical reflection	2(10%)	4(19%)	7(33%)	5(24%)	3(14%)

It is interesting to note that teachers responded more positively to general statements about the science their students actually did (see Table 4.24) than when they were asked about student use of specific science process skills (see Table 4.25). For example, when asked to indicate whether Fast Plants gave their students the chance to raise their own questions and answer them, 38% agreed strongly and 48% agreed. When asked specifically about the level of question raising by students, the response was much lower--24% responded "very often," 48% said "often," 14% said "sometimes," and 14% said "rarely." This suggests that while teachers' goals for their students included learning how to "do science," the amount of practice students had using specific science process skills (other than observation) was actually quite low. Students seemed often to be only asked to "play at doing science," rather than to "do science."

Student Learning

Nearly all the teachers (91%) agreed that students' learning in science had increased through the use of Fast Plants. Almost as many, (86%) thought that students' broad understanding about plants had increased. (86%) said that their students' practical understanding of plants' needs increased. A smaller proportion (62%) thought that "in-depth" learning about specific plant topics had increased, while just over half (52%) said that students' detailed learning about plants had increased. About two-thirds (67%) thought that student learning by their own discovery had increased.

Slightly over half (52%) thought that students had learned more from Fast Plants than from other plant activities, while slightly under half (48%) thought that using Fast Plants had caused students to increase their own initiative and use of imagination.

Table 4.26 Fast Plants and student learning

	Great Increase	Increase	No Change	No Opinion
Student learning	9(43%)	10(48%)	2(10%)	0
Understanding plant needs	8(38%)	10(48%)	3(14%)	0
Grasping big ideas/plants	7(33%)	11(52%)	2(10%)	1(5%)
"In-depth" learning of specific plant topics	3(14%)	10(48%)	7(33%)	1(5%)
Detailed learning/plants	3(14%)	8(38%)	3(14%)	7(33%)
Use of imagination and personal initative	4(19%)	6(29%)	8(38%)	0
Learning by discovery	5(24%)	9(43%)	2(10%)	5(24%)

Nearly all the teachers (95%) also agreed (52% agreed strongly) that previous knowledge and/or success with plants was not necessaary for students to have a successful experience with Fast Plants.

Personal Response to Fast Plants

Students and teachers both responded positively to Fast Plants. They talked about their feelings toward the innovation in terms of pleasure, success, and beauty. Using Fast Plants improved attitudes towards plants and science.

Fast Plants and Fun: Feelings of Pleasure

It is clear that Fast Plants were fun for both teachers and students. Fun, and enjoyment are words that occurred over and over again in teacher comments throughout the three year period. Webster's New Collegiate Dictionary defines fun as "providing enjoyment," and enjoyment as "something that gives satisfaction." Play is defined as "operating freely within prescribed limits," or "dealing in a light or speculative manner," while motivate is defined as "stimulating interest in something."

"Fun" was a word used spontaneously all the teachers (including the teacher whose plants died over winter vacation) during interviews at the end of the first year to describe their own, as well as their students' reaction to Fast Plants. On the questionnaire at the beginning of the second year, nearly all (90%) of the teachers agreed that Fast Plants were fun for both themselves and their students. One teacher (5%) thought Fast Plants were fun only for students, and another thought they were fun only for teachers.

The response was even more favorable on the third year questionnaires. In the final questionnaire, all the teachers agreed that Fast Plants were fun for both students and teachers. They felt this to be especially the case for themselves. Two-thirds felt that Fast Plants were more fun for their students than other plant activities. Teachers listed "fun" as one reason they would recommend Fast Plants to other teachers.

Table 4.27 Fast Plants and pleasure

	Agree Strongly	Agree	Dis-agree	No Opinion
Fast Plants are fun for students	16(76%)	5(24%)	0	0
Fast Plants are more fun than other plant labs	7(33%)	7(33%)	5(24%)	2(9%)
Fast Plants are fun for me as the teacher	19(91%)	2(10%)		

All too often science classes contain neither fun nor play, and are considered "boring," "uninteresting" and "hard" by many students. At the same time teachers seem to judge their own success as teachers in terms of student interest, and their ability to motivate students. Fun and play and the ability to succeed seem closely related to student interest. Fast Plants seemed to provide students an opportunity to enjoy science, to succeed at it, and to play at the same time. And Fast Plants simultaneously gave teachers an excellent motivational tool.

During first year interviews, teachers gave various reasons for Fast Plants being fun: because they "changed so fast," because they were so "easy to do," because students had individual plants of their own, because they were new and different, and because students learned through experience, rather than being told. Two teachers noted that Fast Plants were definitely worth it, in spite of more work, because of the "fun" their students had.

Table 4.28 Why teachers think Fast Plants are fun

	Number of Teachers
High level of student interest	19 (86%)
Good motivational tool	7 (32%)
Speed of life cycle	11 (50%)
Easy to do	2 (9%)
"Doing" science, asking & answering own questions	9 (41%)
Novelty, something new and different	4 (18%)
High level of individual teacher interest	6 (27%)
Lower intellectual requirements than in other labs	3 (14%)

Fast Plants and Self Esteem: Feelings of Success

Teacher comments during the three years suggest that at least a quarter of the teachers felt that Fast Plants helped their students develop self-confidence. Teachers suggested that the material was eminently "do-able" for their students, and that working with Fast Plants helped their students improve their own self-esteem. With Fast Plants teachers did not equate "being easy to do" with being inappropriate to science class. This is unusual, since part of the mystique of science built up by teachers is its difficulty. One teacher mentioned that for students it was a relief to do something that was more concrete, less abstract, and less difficult than other topics like molecular biology. A student noted that "working with Fast Plants is so much fun. It's too bad we have to start studying science again soon."

Throughout the three year period, teachers frequently spoke of the "success" that their students felt, and of a "sense of empowerment." In interviews at the end of the first year, nine teachers (41%) commented on success, empowerment, personal identification and the development of responsibility as being important effects that the material had on their students.

Students were proud of their plants. Nine teachers (41%) mentioned that the first thing that students did when they came into the room was to check their plants, and three (14%) noted that their students brought their friends in to see their plants. One teacher thought that individual ownership of plants in the classroom encouraged students to become more responsible in caring for the plants. Another commented, "The students felt some kind of an ownership, a kindredship that normally wouldn't be there." Four others noticed much the same thing, and hoped that the feelings students developed toward their own plant might help them become generally more humane, and develop a greater sense of stewardship toward all forms of life.

Students were reluctant to thin their seedling, preferring to thin rather than "kill" them. A number of teachers commented on the fact that their students were unhappy if their plants died. One student, whose plant died, made a gravestone with the epitaph, "Peter Plant, R.I.P."

Fast Plants and Aesthetics: Feelings about Beauty

There is little direct evidence about the effect of Fast Plants on the development of esthetic appreciation by students, although in the initial teacher questionnaire nearly a third (32%) of the teachers said that they wanted their students to appreciate the "beauty" or "wonder" of plants. Continuing comments by teachers throughout the 3 year period suggest that an appreciation of nature was an important reason for teaching about plants. Teachers spoke of their own "love of plants," and of thier hope that their students would appreciate the "beauty" of nature through their use of Fast Plants.

Informal student conversations overheard by this researcher suggest that the beauty of Fast Plants was not lost on the students. For example, one group of middle school boys were overheard to agree that they hoped they could take their Fast Plants home as Mother's Day presents "because they are so beautiful."

Student Attitudes, Interests, and Fast Plants

Teachers said they had seen positive changes in student attitudes, which were reflected in changes in student interest. Teachers considered Fast Plants to be a highly successful motivational tool. Most (85%) thought their students' interest in studying about plants and experimenting with plants increased after they had used Fast Plants in the classroom. More than three-quarters (77%) thought that student experience with Fast Plants had helped them improve their attitude toward science in general. A slightly smaller percentage (57%) thought that growing Fast Plants at school had increased student interest in raising other plants or in gardening.

Teachers agreed less strongly that Fast Plants related to their students' natural innate interests, or that they were particularly relevant to the everyday experiences of their students. This finding seemed a bit surprising. It suggests that either the teachers are unaware of the importance of relating experiences students have in their science class with their everyday world, or that the questions asked by the researcher were awkwardly worded, and misunderstood by participants.

Table 4.29 Student interest and Fast Plants

Student interest in:	Increased Greatly	Increased	No Change	No Opinion
studying about plants	2(9%)	16(76%)	3(14%)	0
experimenting with plants	8(38%)	10(47%)	3(14%)	0
raising plants and/or gardening	5(23%)	7(33%)	3(14%)	6(28%)

Fast Plants:	Very Much	Some-what	A Little	Not Much	No Opinion
relate to students'natural innate interests	4(19%)	13(62%)	3(14%)	0	3(29%)
have relevance & meaning in students' lives	4(19%)	4(19%)	4(19%)	1(5%)	8(38%)
help relate teaching to students' everyday lives	3(14%)	10(48%)	1(5%)	4(19%)	3(14%)
improve student attitude toward science	6(29%)	10(48%)	2(10%)	0	3(14%)

Teacher Attitudes, Interests, and Fast Plants

Using Fast Plants increased teacher interest in teaching about plants, as well as their interest in learning about plants. At the end of three years nearly all the teachers (91%) indicated their interest in learning about plants and in experimenting with them had increased.

Three-quarters of the teachers (76%) indicated their interest in teaching about plants had increased.

Table 4.30 Teacher interest and Fast Plants

Through Fast Plant use teacher interest in:	Great Increase	Increase	No Change	Decrease
teaching about plants	8(38%)	8(38%)	5(24%)	
learning about plants	6(29%)	13(62%)	2(10%)	
experimenting/plants	4(19%)	15(71%)	1(5%)	1(5%)

Another indication of teacher interest in plants might be inferred from the large number of spontaneous questions teachers asked during interviews at the end of the first year. 17 (77%) of the teachers asked at least one botanical question during the first year interview; the average number of such questions per teacher was 3.2.

Teacher Professional Development

Nearly all of the teachers (90%) believed that Fast Plants had helped them to grow professionally. 14 of the 18 teachers responding agreed that using Fast Plants had helped them to become better teachers, while two-thirds thought they had become more creative teachers, and had developed more imaginative lessons.

Table 4.31 Fast Plants and teacher professional development

Fast Plants encouraged me to:	Strongly Agree	Agree	No Change	Dis-agree	No Opinion
grow professionally	7(33%)	12(57%)	2(10%)	0	0
be a better teacher	7(33%)	7(33%)	4(19%)	0	3(14%)
become a more creative teacher	7(33%)	7(33%)	7(33%)	0	0
develop more imaginative lessons	5(24%)	9(43%)	5(24%)	1(5%)	1(5%)

Nearly three-quarters (72%) thought that using Fast Plants had helped them to learn more about plants. Nearly as many (67%) thought they had learned at least as much as their students.

Table 4.32 Fast Plants and teacher learning about plants

Fast Plants:	Strongly Agree	Agree	No Change	Dis-agree	No Opinion
Helped me learn more about plants	2(10%)	13(62%)	5(24%)	0	1(5%)
Caused me to learn at least as much as the students	9(43%)	5(24%)	2(10%)	2(10%)	3(14%)

A substantial proportion (71%) thought that using the innovative material had helped them learn more about how their students learn. Although three-quarters of the teachers thought they had become more aware of what their students misunderstood about plants, and could better assess student knowledge about plants, far fewer (33%)

thought that using Fast Plants had helped them develop better tests or assessment methods.

Table 4.33 Fast Plants and teacher knowledge about student ideas about plants

Using Fast Plants helped me:	Very Much	Some-what	Not Much	None	No Response
learn how my students learn	4(19%)	11(52%)	3(14%)	1(5%)	2(10%)
learn about student misunderstandings	7(33%)	9(43%)	2(10%)	1(5%)	2(10%)
better assess student knowledge about plants	8(38%)	8(38%)	3(14%)	1(5%)	1(5%)
develop better tests/ assessment methods	1(5%)	6(28%)	6(29%)	4(19%)	4(19%)

Fast Plants had a less pronounced effect on the teaching methodologies of the participants. A little more than half (55%) thought there had been some change in the past three years, while the rest said that there had been no change. Slightly more than one-third of the teachers (39%) thought that at least part of the change had been due to using Fast Plants. Just about a third (35%) were planning other changes in the near future, while the other two-thirds were not.

Table 4.34 Fast Plants and changes in teaching methodology

	YES	NO
Teaching methodology changed in past 3 years?	11 (55%)	9 (45%)
Plan any changes in the near future?	7 (35%)	13 (65%)

Extent of change in teaching methdology using Fast Plants:	
Very much	1 (5%)
Somewhat	2 (10%)
A Little	5 (24%)
No Change	7 (33%)
No Response	6 (29%)

Many of the teachers were making use of cooperative learning groups, a technique they had learned during earlier NSF summer institutes. Eleven teachers (52%) said their use of cooperative groups had increased during the past three years, while 39% of the teachers said that cooperative work had increased since using Fast Plants. For one teacher, finding it difficult to move away from a very traditional teacher centered pedagogy, Fast Plants provided the impetus to try cooperative groups with his classes for the first time. He was delighted with the success, pleased with the high level of student performance, and relieved that he did not lose control of his class, which he had feared.

Table 4.35 Fast Plants and cooperative learning groups

Amount of cooperative learning group work used in the classroom:	
Great deal	6 (29%)
Some	9 (43%)
Very little	2 (10%)
None	0
No response	4 (19%)
Use of cooperative learning groups during past 3 years:	
Increased	11 (52%)
Not increased	6 (29%)
No response	4 (19%)
Amount of cooperative learning group work since using Fast Plants:	
Increased greatly	2 (10%)
Increased	6 (29%)
No change	9 (43%)
No response	4 (19%)

Dissemination of Fast Plants to Others

One way to test positive teacher response to an innovation is by looking at whether they share it with others. The level of dissemination of information about Fast Plants was very high among participants in this study. Every teacher told at least a few other teachers about Fast Plants, and the positive experience they had with the material. Some talked to only a few people; others spoke with many. One teacher reckoned the number to be "in the hundreds;" for another it was "more than you could count." A third spread the word to "anyone who would listen."

Teacher enthusiasm was infectious. Participants told colleagues in their own schools, friends in other schools, principals, superintendents, parents. They talked about Fast Plants in classes they were enrolled in and at meetings they attended. One teacher shared information about Fast Plants with other teachers through a telecommunications network.

Table 4.36 Telling others about Fast Plants

Teachers	Number Other People Told about Fast Plants
6	2-6
6	10-25
4	40-50
5	over 50

By the end of the third year, Fast Plants were being used by additional teachers in the school systems of more than half (52%) of the participants. In five cases, the other users were in the same school; in the rest, the new users were in different schools. One participant was responsible for Fast Plants being used in every school in town (one elementary, one middle and one high school). At the end of the third year she was planning a workshop for all the elementary school teachers in the town. Her goal was to persuade every teacher in the elementary grades to use Fast Plants (in different ways in each grade). Two participants persuaded their departments to order materials for others to use in the following (fourth) year. Yet in another school, the participating teacher was disappointed because the Fast Plant kits that he had persuaded his department chairman to purchase were not being used by his colleagues.

Many of the participating teachers, on their own initiative, began to present workshops to introduce others to the innovation. One-third (7) of the participants had given at least one Fast Plant workshop by the end of the third year. These included presentations to colleagues in their own science departments and to other teachers in their school systems, to teachers in other school systems, and at local, state or national professional meetings. Two teachers, who had not previously presented workshops, were planning workshops during the fall of the fourth year.

Table 4.37 Fast Plant workshops presented by teachers

Number of Workshops Presented:	
1	1 Teacher
2	3 Teachers
3	1 Teacher
5	1 Teacher
15	1 Teacher

Many in the group also demonstrated their continuing interest in Fast Plants by attending the two additional Fast Plant workshops held during the 3 year period of the study. 12 of the teachers (57%) attended the workshop at the beginning of the second school year, at which participants shared ideas, and nine (43%) attended the three-day workshop presented by Professor Paul Williams, Fast Plants' developer, during the summer following the second year.

CHAPTER 5

DISCUSSION OF THE RESULTS

Overview of the Study

This inquiry has been undertaken to evaluate the usefulness and effectiveness of an innovative plant material, Fast Plants, in middle and high school science teaching. The research spans a 3 year period. and conclusions are drawn from a sample population of 22 teachers who volunteered to use Fast Plants in their classrooms.

The research has been undertaken to learn how the teachers in this group used Fast Plants, and any changes that took place in their classrooms attributable to the use of the innovation during the 3 year research period.

The population sample under study was drawn from a group of New England middle and high school teachers who had attended either of two summer science education institutes held at a New England college. These teachers were invited to attend an introductory one-day workshop on Fast Plants. Teachers who attended the workshop, and were interested in using Fast Plants in their classroom during the subsequent year, were invited to participate in the study. All who volunteered were accepted. The group was not meant to represent a cross-section of science teachers in general, but only that sub-group of teachers who exhibit a strong commitment to their own professional development, and who attempt to improve their performance as teachers.

Teachers who volunteered to participate were asked to use Fast Plants with one or more groups of students of their own choosing during the subsequent school year. They were given all materials and equipment for raising Fast Plants in their classrooms, as well as a packet of background information and brief descriptions of possible classroom uses of the innovative material. No complete curriculum or detailed prescriptive lesson plans were included.

Teachers were free to use Fast Plants in any way they wished, and were encouraged to use the material in a manner that suited them best. After the first year, no attempt was made to encourage the continued use of Fast Plants by teachers in the sample population. The choice to do so was entirely up to each individual teacher. Communication was maintained with teachers, whether or not they continued to use Fast Plants, throughout the 3 year period by telephone and mail, and technical assistance was provided upon request. Two additional workshops were held during the 3 years of the research. 12 of the teachers attended the first follow-up workshop in the fall of the second school year; nine teachers attended another during the following summer.

During the first year, site visits were made to the classrooms of participants, and all teachers were interviewed after using Fast Plants with their students. Instruments used for data collection included personal and telephone interviews, questionnaires, and classroom observations. The instruments were developed sequentially by the researcher, building on data collected and ideas generated by previous instruments. The findings reported in detail in Chapter 4 are based primarily on quantitative data collected in the final summative evaluation.

Summary of Results of the Inquiry

The results of this inquiry show that participating teachers judged Fast Plants, to be an effective and useful teaching material. The findings of the research can be summarized as follows:

1) Technically, Fast Plants worked well in a variety of classrooms, and lived up to teacher expectations for performance.
2) Every teacher used Fast Plants with one or more groups of students during the first year of the study. The level of use remained high during the second and third years: 88% of those teaching used Fast Plants during the second year, and 94% used them in the third. There were increases in both the number of classes

using Fast Plants, and in the kinds of uses made of the material.

3) A substantial number of teachers (86%) increased the time they spent on plant studies during the 3 year period; slightly more than half (52%) increased the number of different plant topics they taught. 76% felt that using Fast Plants had encouraged them to increase the time they spent on plant study, and that Fast Plants had helped them to teach plant topics more effectively. 43% thought they spent more time on plants than other teachers in their schools.

4) By using Fast Plants, teachers increased the amount of lab work their students did with live plant materials, and the number of extended long-term investigations undertaken in the classroom.

5) Nearly all teachers (98%) felt that student learning increased, and most (86%) felt that student understanding of basic concepts about plants increased through the use of Fast Plants.

6) Fast Plants were enjoyable for both teachers and students. At the end of the study all teachers agreed that Fast Plants were "fun" for both students and teachers. Teachers also felt Fast Plants helped students develop self-confidence, improved student attitudes toward science, and increased student interest in plants and plant study.

7) Most teachers (90%) believed that their work with Fast Plants helped them to grow professionally. Two-thirds (66%) of them felt that Fast Plants had helped them to become better teachers. The same number felt the innovation had helped them to become more creative teachers, and to develop more imaginative lessons.

8) Teachers expressed their positive response to Fast Plants by telling others about the innovative material. Every teacher told other educators about Fast Plants. 33% had given at least one professional workshop on Fast Plants by the end of the third year.

Two characteristics of the innovation--its accessibility and its flexibility--seem especially important with respect to its success. All the participating teachers found Fast Plants to be an excellent teaching tool, regardless of their previous experience with plants, or their botanical background. All found Fast Plants very easy to use in the classroom. The material was accessible to students of a wide range of ages and abilities. In general, students appeared to enjoy working with Fast Plants, and feel a great sense of pride in their successes in growing and caring for the plants. Beyond all the specific quantitative data, a thread runs through the findings which suggests the importance of personal feelings about science, and the importance of having fun and feeling successful in science.

The flexibility of the innovation is also a very important characteristic with respect to its success. The material was useful in many different ways. Even during the first year (when many admitted they simply hoped they could keep the plants alive in the classroom), all the teachers did not use Fast Plants in the same way. As teachers became more comfortable with the innovation, many undertook an even wider range of uses for the innovation. Some teachers integrated Fast Plants into other innovations they were attempting to implement in their classrooms. A few made major changes in their classroom practice; others made minor adjustments, but only a few seemed satisfied to limit themselves to a single successful use. At the end of the 3 years, some were considering a range of changes in their teaching that in some way or other were related to Fast Plants.

The results of the study indicate that in actual use Fast Plants meet all the criteria of good learning materials. They are appealing and interesting to students. They stimulate their curiosity and help them develop positive attitudes toward doing science. They can be used in the classroom with students of a broad range of ages and abilities. They are simple, safe, inexpensive and easy to use. They are flexible, and can be used in a wide variety of ways in the classroom. Furthermore, for the teachers in this study, using Fast Plants changed both how they taught science and what they taught.

Implications of the Results for Future Research

The findings of this study suggest a number of inquiries that might be undertaken in the future. First, it would be interesting to compare use by teachers who are required to use the material, with those who use it by choice.

Second, the availability of Fast Plants provides an opportunity to learn more about the particular ideas that students of various ages hold about a whole set of plant related science concepts. Several participating teachers in this study noted that Fast Plants had a major impact on the conceptual understandings of their students, providing an real opportunity for them to test their existing ideas against new evidence. This suggests a whole set of studies on the development of conceptual understandings and the use of Fast Plants.

Third, results from this study point to an inconsistency between teacher goals, classroom pedagogy, assessment methods, and student learning. Much of the science teachers expected their students to learn was detailed and specific. Yet the teachers set their goals in much broader terms, hoping for example that their students would develop an "understanding" of science, or an "appreciation" of nature. This paradox needs to be explored further. More could be learned about the interface between teachers' perceptions of science, their teaching methodology, their goals for student learning, and actual student achievement.

The effects of Fast Plants on teachers' core concepts of knowledge, learning and teaching could also be studied in greater detail, perhaps using ethnographic and case study techniques. In the current study, Fast Plant use caused a substantial number of participants (9) to reconsider their core concepts about learning and teaching. A few made major changes in their own practice; others appeared to be on the verge of doing so at the end of the 3 years.

Fifth, the relationship of innovative material (especially Fast Plants) and "fun" ought to be explored further. Since using Fast Plants was an especially enjoyable experience for both students and teachers, it offers an opportunity to study the role that pleasure and personal feelings play in successful achievement in science. A variety of studies might be set up to explore this relationship with Fast Plants, and also to compare Fast Plants with a number of other teaching materials, both old and new.

Sixth, studies comparing the effectiveness of the informal training and support model used in this study might be with other approaches might be made. The effectiveness of the model used in this study might also be tried with other innovative materials, especially other innovations from science and technology. Such studies might suggest effective new ways to disseminate such innovations to teachers, as well as useful ways to train teachers in the uses of innovative materials, as well as more effective forms of continuing support.

Lastly, several more general studies come to mind. Although background information has been collected in this study about the teaching of plant topics by one particular group of teachers, a review of the literature indicates that little information exists about both general patterns and particulars of botanical teaching in American classrooms. Much more that might be learned about the teaching about plants: the topics covered, approaches taken, differences and similarities of coverage and goals at various levels, and so on.

There is little to be found in the literature about teachers' level of understanding of basic plant concepts. Comments and questions from individual participants in this study suggest a lack of basic knowledge among many in a group of highly educated teachers. More information from a larger and more representative sample of teachers would be helpful.

Implications of the Results for Teaching Practice

There are a number of important implications of the results for improving teaching practice. The findings of this research show Fast Plants to be a highly effective and useful teaching material in middle and high school classrooms. Teachers who used Fast Plants increased the time and attention given to the study of plants. Students spent more time using live materials to "do science" in the classroom. Positive changes were noted by teachers in student interest in plants, as well as increases in their understanding of basic plant concepts.

It is interesting to note that Fast Plants appeared to encourage many teachers in the group to move out of the traditional role of 'teacher as expert.' Several commented that while working with Fast Plants, they felt they were not expected to have all the answers, because the plant cultivar was so new. Being a learner, as well as a teacher, was a novel and pleasant experience for many in the group.

This suggests that the significance of the innovation may be greater than just its ability to increase the amount of teaching on plant topics, or even in increasing the amount of time students spend doing investigative work with plants in the classroom. Its real significance may be in helping teachers reconsider their own basic understandings of teaching, learning, and the basic nature of scientific knowledge. This in turn may lead to real and lasting reform in American science education.

Future Program to Improve Science Teaching

It is important to remember that change is a highly personal process, an irregular montage of emotional, intellectual, and behavioral responses, unique to each individual. Successful implementation of any change takes time, and a great deal of energy. Appropriate interventions, geared to the specific needs of individuals, are important to facilitate the change process. Teachers, while trying to use an innovative material, change their classroom practice, and grapple with their own understandings about science, teaching and learning, need all the help they can get.

In conclusion, a set of four interrelated programs are suggested, which might encourage the use of Fast Plants, and also improve science teaching in general.

1. Teacher Academies in Plant Science, designed to introduce teachers (of all levels) to Fast Plants, and enlarge and update background knowledge about plants in general. Participants would have the opportunity to do many activities with plants, and especially Fast Plants, and undertake scientific investigations of their own design. Teachers would also be introduced to recent research on the learning process, and have the opportunity to meet a variety plant specialists.

   After using Fast Plants, participants in this study raised a wide variety of questions about plants, and their interest in plant study increased. At the end of the three years, a substantial proportion of participants (90%) were either "definitely" or "probably" interested in attending summer institutes on plants. This suggests that a brief exposure to Fast Plants increases teacher interest in learning more about botanical topics.

Few, if any, programs exist which focus on helping teachers increase their knowledge about the plant world, and probably none that link together theories of teaching and learning, an innovative plant cultivar (Fast Plants), and teacher experience in the classroom. Non-traditional time frames, such as one or two days a week for two or three months, might be considered as well as shorter full-time programs.

2. <u>Technical Support and Classroom Assistance Programs</u>, which would offer both technical assistance on questions related to Fast Plants, and assist teachers in making pedagogical changes. A range of different kinds of support models might be developed, and the results of each compared.

3. <u>Local and Regional Teacher Networks</u>, which would include teachers of any level (kindergarden through college) using Fast Plants and or with an interest in plant studies. Teacher linkages might be maintained through newsletters and/or telecommunication networks. A series of informal school year workshops could be

developed to encourage a continuing dialogue between teachers at all levels who share an interest in plants. Teacher networks usually focus on a single level, and rarely encourage the involvement and exchange of ideas between teachers at various levels, as these would do.

4. <u>Academic Alliances between Research Scientists and Teachers using Fast Plants</u>, would link together those using Fast Plants primarily as a research tool and those using it as a teaching tool. The goal would be to develop academic alliances between researchers and teachers, in which both could enlarge their understanding of the learning and teaching processes and improve science education.

APPENDIX A

INTRODUCTORY WORKSHOP, YEAR 1

Program: Introductory Workshop, Year 1

Material and Equipment Provided to Each Teacher at the Introductory Workshop

Information on Fast Plants
- Fast Plant Growing Instructions
- Fast Plant Schedule and Instructions for Making Bee Sticks
- The Brassica Flower
- Pollination
- Growth, Development and Reproduction
- Life Cycle of Rapid Cycling *Brassica rapa*
- Around the World with Brassicas

Fast Plant Activities

Activity 1: Growth, Development and Reproduction
Activity 2: Investigation of Flower Structure
Activity 3: Influence of Acid Rain on Plant Growth
Activity 4: Is More "Food" Better?
Activity 5: Mendelian Genetics
Activity 6: Comparing Pollination Success of Bees and Houseflies
Activity 7: Salt Pollution
Activity 8: The Effects of a Virus on Plants
Activity 9: Effects of Plant Hormones

PROGRAM: INTRODUCTORY WORKSHOP, YEAR 1

BACKGROUND: the new plant cultivar, Wisconsin FAST PLANTS (rapid cycling Brassicas) offers exciting new possibilities for hands-on classroom studies. FAST PLANTS have unique properties, making them ideal teaching tools. Their rapid growth provides quick feedback. They are small and hardy and can complete a life cycle in 40 days, producing seed students can immediately harvest and replant. They are easy to grow within the classroom under standard cool white fluorescent lights. Most importantly, FAST PLANTS can be used to illustrate aspects of biology such as growth and development, bee pollination, reproduction, photosynthesis, nutrition, photo responses, genetics and ecology.

WORKSHOP ACTIVITIES:

INTRODUCTION TO FAST PLANTS: Introducing teachers to the economically important Crucifer family of plants (cabbages, mustards, etc.) and to FAST PLANTS.

LABORATORY: Hands-on activities with FAST PLANTS to learn the proper techniques for growing and using the plants in the classroom.

1. Variation in populations: Each participant opens a seed pod, observes seeds (color, number of seeds, seed size, etc.) Make a chart showing variation in seed size.
2. Making bees sticks: Make bee sticks following instructions on handout.
3. Discussion of the life cycle of FAST PLANTS and the method for growing them in the classroom: Review Growing Instructions sheet. Point out light banks, watering resevoirs, etc.
4. Planting FAST PLANT seeds
5. Comparing the germination of FAST PLANTS with radish and mustard seeds using petri dishes and 2-3 day old plants.
6. Flower structure of FAST PLANTS: Using a hand lens (or stereo scope) observe the flower structure of FAST PLANTS.
7. Pollinating FAST PLANTS using bee sticks: Compare the amount of pollen you can pick up with bees, Q-tips, and camel hair brushes.
8. Genetics: Inhertance of both Mendelian and non-Mendelian traits: Pass around examples of single gene recessive traits: eh (elongated hypocotyl); yg (yellow green cotyledons); var

(variegated [maternally inherited]); <u>ro</u> (rosette [lacking gibberellic acid]). Discussion of study of genetics using FAST PLANTS.

9. Demonstration and discussion of other activities using FAST PlANTS: phototropism, geotropism, photosynthesis, nutrition, water excesses and deficencies, light intensity, photo period, acid rain, air pollution, salt pollution, herbicides, effects of pests and diseases.

PLANT LESSON SHARING: Participants asked to bring successful ideas for plant study they have used in the classroom to share with other participants at the workshop.

REQUEST FOR VOLUNTEERS TO PARTICIPATE IN THE RESEARCH STUDY. Volunteers complete Initial Teacher Questionnaire and Letter of Consent.

HANDOUTS TO WORKSHOP PARTICIPANTS:

1. Packet of background information on Fast Plants
2. Suggestions for classroom activities
3. Two articles on Fast Plants:
   a. Williams, P. H. & Hill, C. B. (1986). Rapid-cycling populations of Brassica. <u>Science</u>,232, 1385-1489.
   b. Williams, P. H. (1980). Bee-sticks, an aid in pollinating Cruciferae. <u>HortScience</u>, 15(6), 802-803.

MATERIALS AND EQUIPMENT PROVIDED TO EACH TEACHER AT THE INTRODUCTORY WORKSHOP

Each teacher provided with the following materials and equipment (for use with one class of 32 students):

rapid-cycling <u>B. rapa</u> seed

tetrads (4-celled growing containers)

potting soil

Osmocote fertilizer pellets (14-14-14)

water resevoirs and platform, wicks, water matting

plastic pot labels

dried bees (for making bee sticks)

wooden support stakes

copper sulfate squares (for algal control)

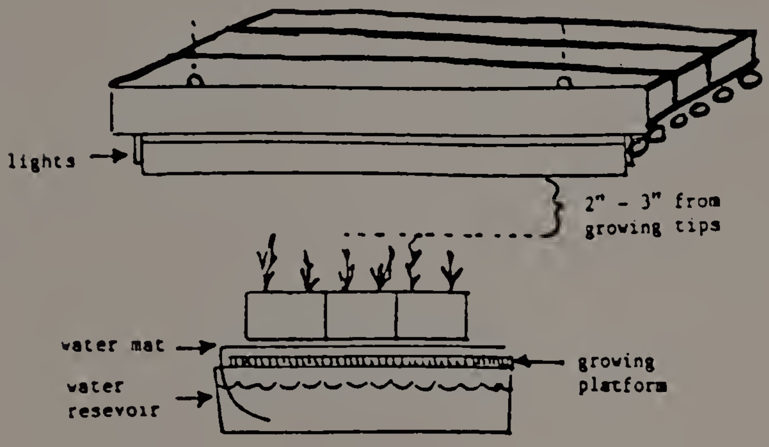
light fixtures for growing plants (3 sets of 2 bulb, 40 watt fluorescent lights).

FAST PLANT GROWING INSTRUCTIONS

WISCONSIN
FAST PLANTS
Patent Pending

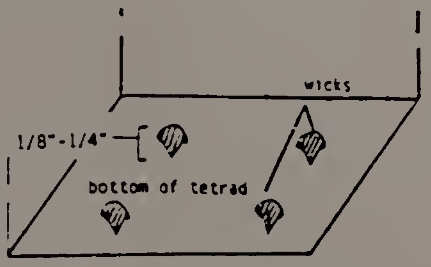
University of Wisconsin-Madison
Department of Plant Pathology-Fast Plants
1630 Linden Drive
Madison, Wisconsin 53706
(608) 262-8638

GROWING INSTRUCTIONS

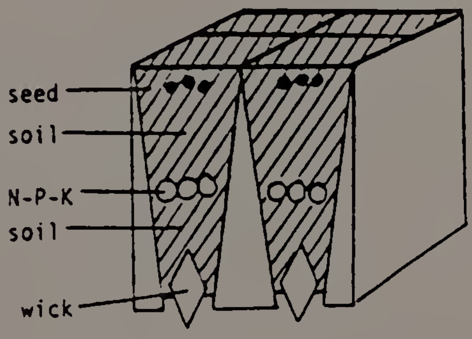


Prior to planting

1. Assemble light banks.
2. Put copper sulfate squares in water reservoirs (1 square/liter water) and fill with water. (Prevents algae growth.)
3. Saturate water mat (dripping) and lay over growing platform with one end extended into water reservoir.

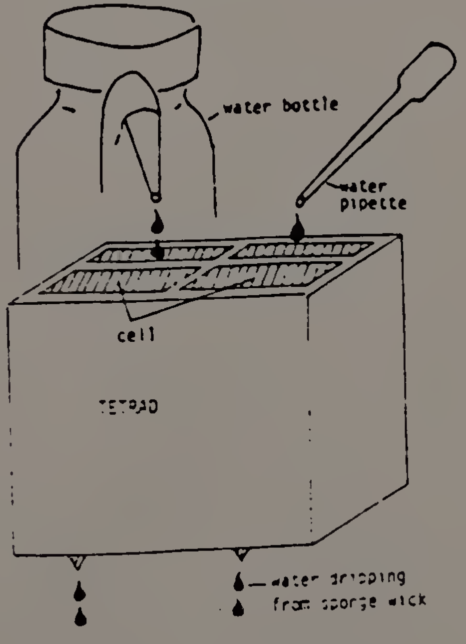


The WATERING SYSTEM is based on wicking (capillary) action. The water mat draws water from the reservoir onto the platform. Wicks in the bottom of each cell draw water into the soil. The water reservoir holds enough water to last 2-3 days (over weekend).



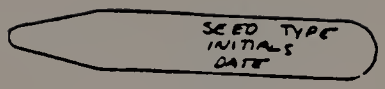
Day 1: PLANT
1. Moisten potting mix (slightly damp, NOT muddy.)
2. Drop one wick into each cell so that the tip extends out the hole in the bottom.
3. Fill each cell halfway with potting mix.
4. Add 3 N-P-K pellets (fertilizer.)
5. Add more potting mix to fill each cell.
6. Make a shallow depression with finger on top of each cell.
7. Drop 3 seeds into the depression.
8. Cover with potting mix.

WATER very gently with pipette or watering bottle until water drips from each wick tip. For best results, water pots from the top for the first three days then simply keep reservoirs full.



Day 1 continued:

LABEL each tetrad. Use pot label (fine tipped waterproof pen) or write directly on tetrad (laundry marker).



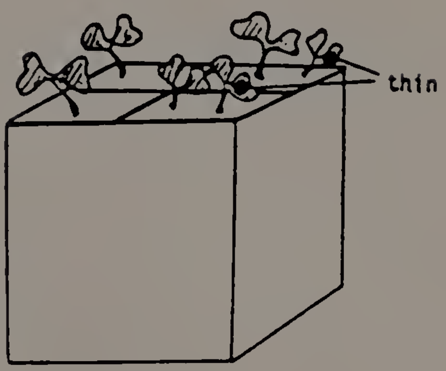
pot label

PLACE TETRADS ON WATER MAT. Position tetrads 2" below the lights. Keep tops of plants 1" to 3" below the lights. Because light waves radiate out in circles from the bulbs the light energy decreases very rapidly as the distance between the plants and lights increases.

Day 2-3: Cotyledons emerge.

Day 4-6:

THIN to one plant per cell. Use scissors or tweezers. Transplant extra seedlings to cells without plants.



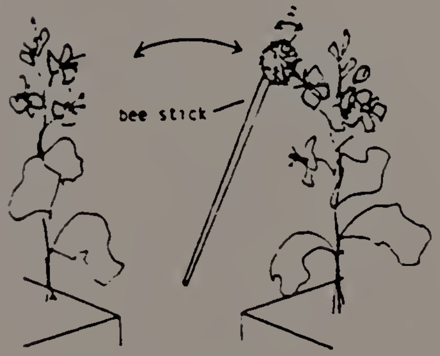
Day ~~13~~ 14: Make bee sticks

Day ~~[illegible]~~ 16-20:

POLLINATE with bee sticks for two to three days.

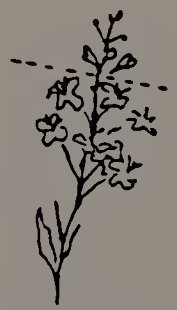
1. Rotate bee thorax over flowers to pick up and distribute pollen.
2. Transfer pollen back and forth among plants. Fast Plants do not self pollinate.

PINCH OFF UNOPENED BUDS on last day of pollination and mark the date on plant stakes or tetrads.



cross pollination

Day 17-~~[illegible]~~ 40: Seed pods and seeds develop. Seed pods will begin to elongate within 3-5 days, embryos will mature in 20 days.



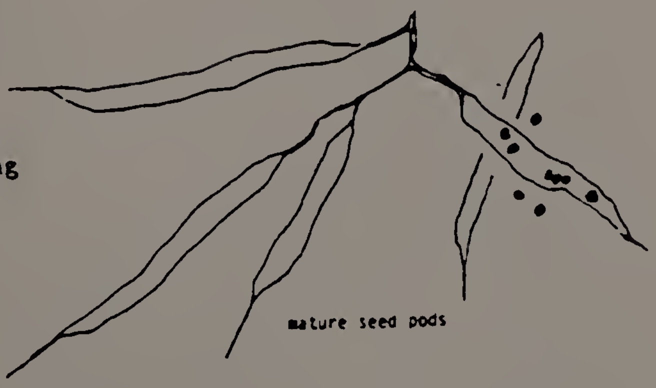
Pinch off unpollinated buds

Day ~~[illegible]~~-40:

REMOVE PLANTS FROM WATER 20 days after last pollination. Dry for 5 days. To cut drying time to 3 days, place seed pods in pans or paper bags (dry seed pods will shatter easily) and set on top of lights. To cut drying time to 2 days, place pans or bags in a drying oven (no warmer than 90F)

Day 42-45:

HARVEST SEED by gently rolling dry seed pods between hands over a collecting pan. Store seed in an appropriately labeled envelope.



mature seed pods

FAST PLANTS SCHEDULE
AND INSTRUCTIONS FOR MAKING BEE STICKS

WISCONSIN
FAST PLANTS
Patent Pending

University of Wisconsin–Madison
Department of Plant Pathology–Fast Plants
1630 Linden Drive
Madison, Wisconsin 53706
(608) 262-8638

FAST PLANTS SCHEDULE

Fill in the calendar dates and tape onto your light rack or plant cart

Name of Experiment ______________________________

Class ______________________________

Calendar date	Schedule	
	Preparation	Set up light banks Set up reservoirs Assemble all materials
	Day 1	Plant, water, label Set 2" from lights
	Day 2-3	Cotyledons emerge Water from top
	Day 4-5	Thin to 1 plant/cell
	Day 13	Make bee sticks
	Day 14-18	Pollinate for 2-3 days Pinch off growing tips on last pollination day
	Day 17-35	Seed pods develop Embryos mature in 20 days
	Day 36-40	Remove plants from water Allow seeds to dry for 5 days
	Day 41-46	Plant your own seeds!

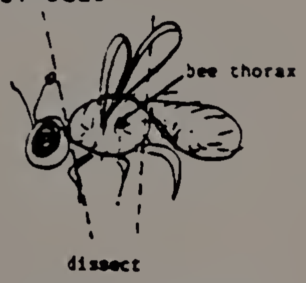
NOTES:

CUT

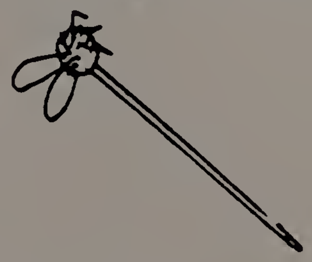
MAKING BEE STICKS

Materials:
- bees
- toothpicks
- fast-drying glue (Duco Cement)
- styrofoam cups

DISSECT BEES



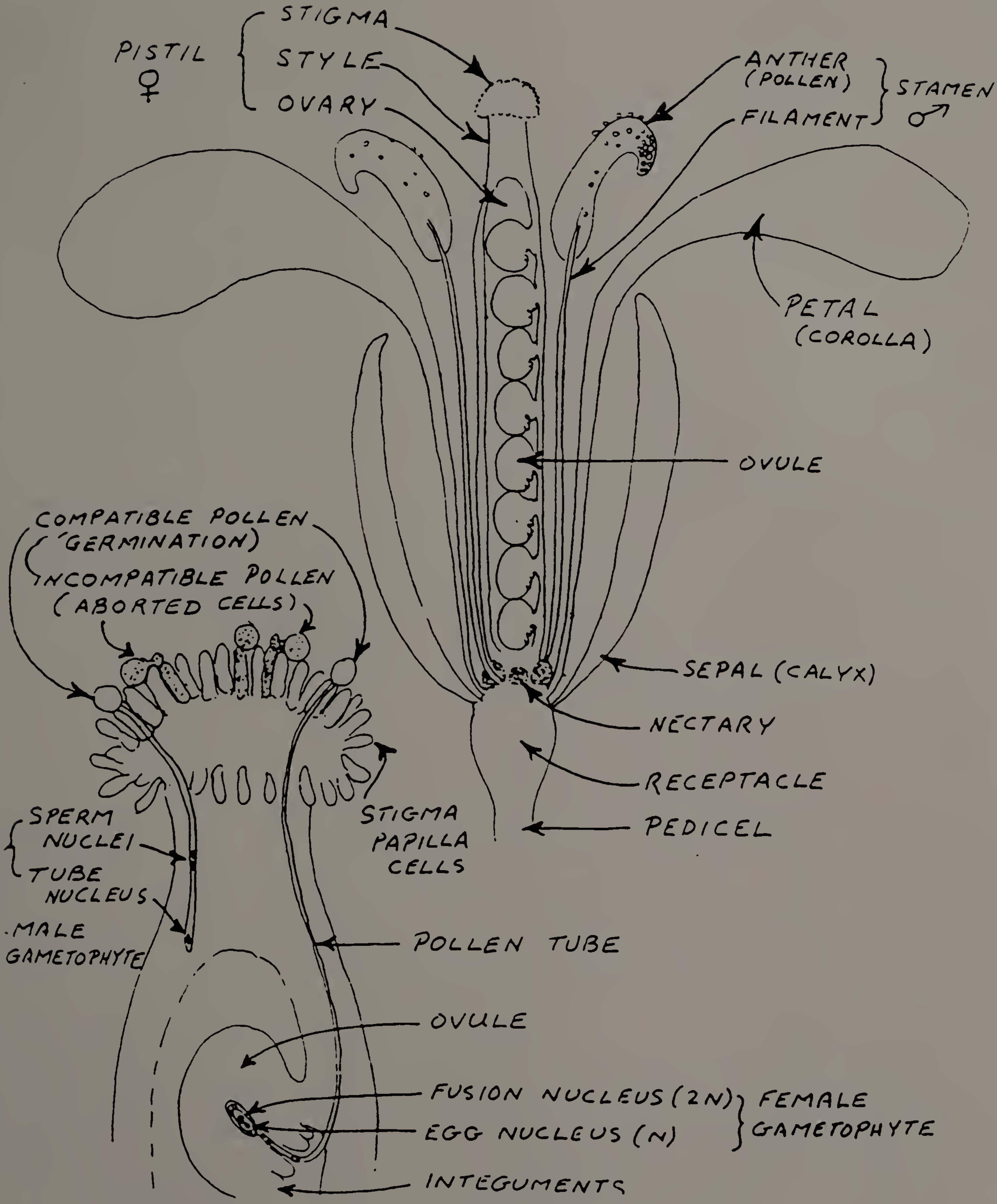
GLUE THORAX TO TOOTHPICK

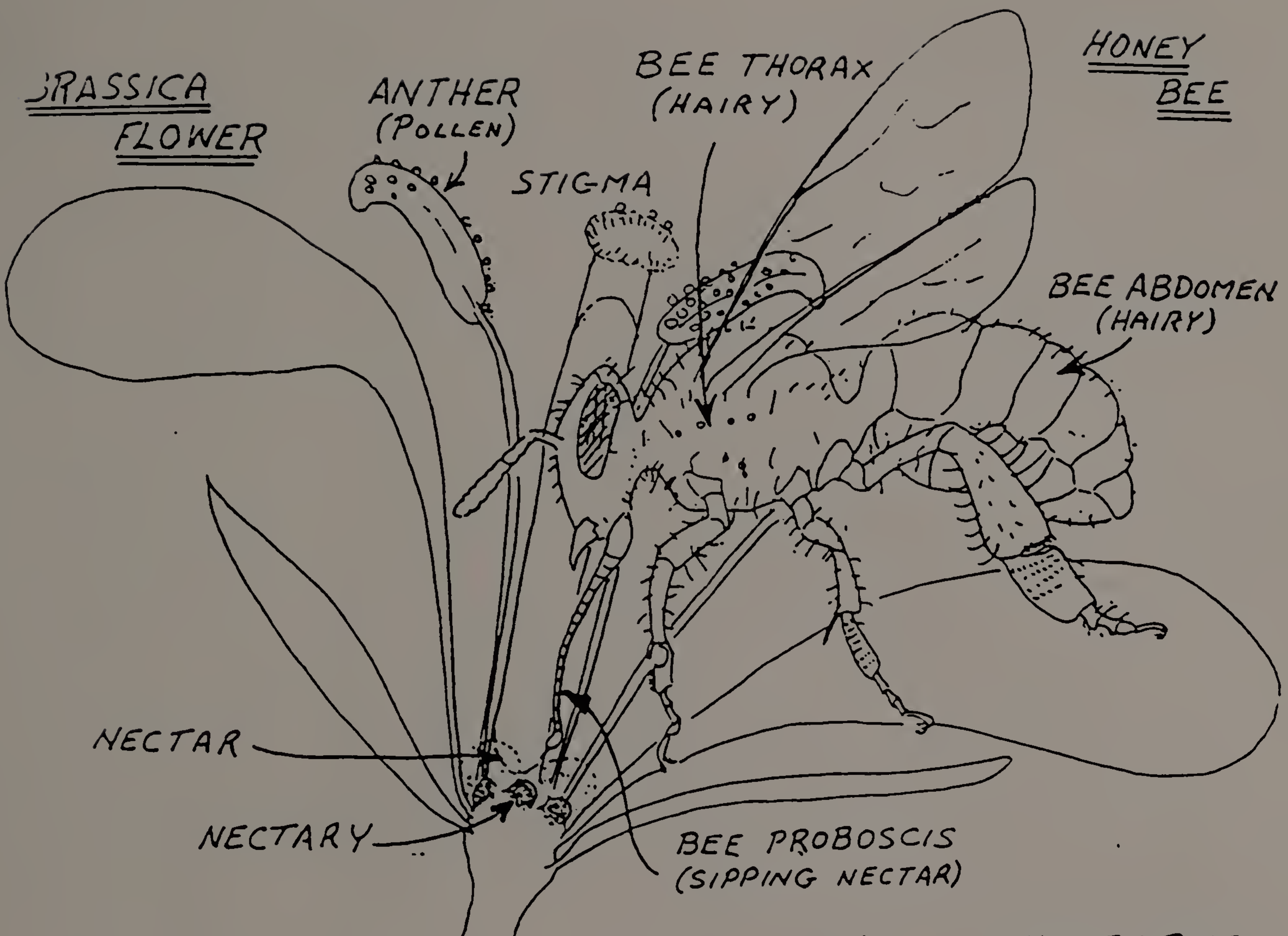


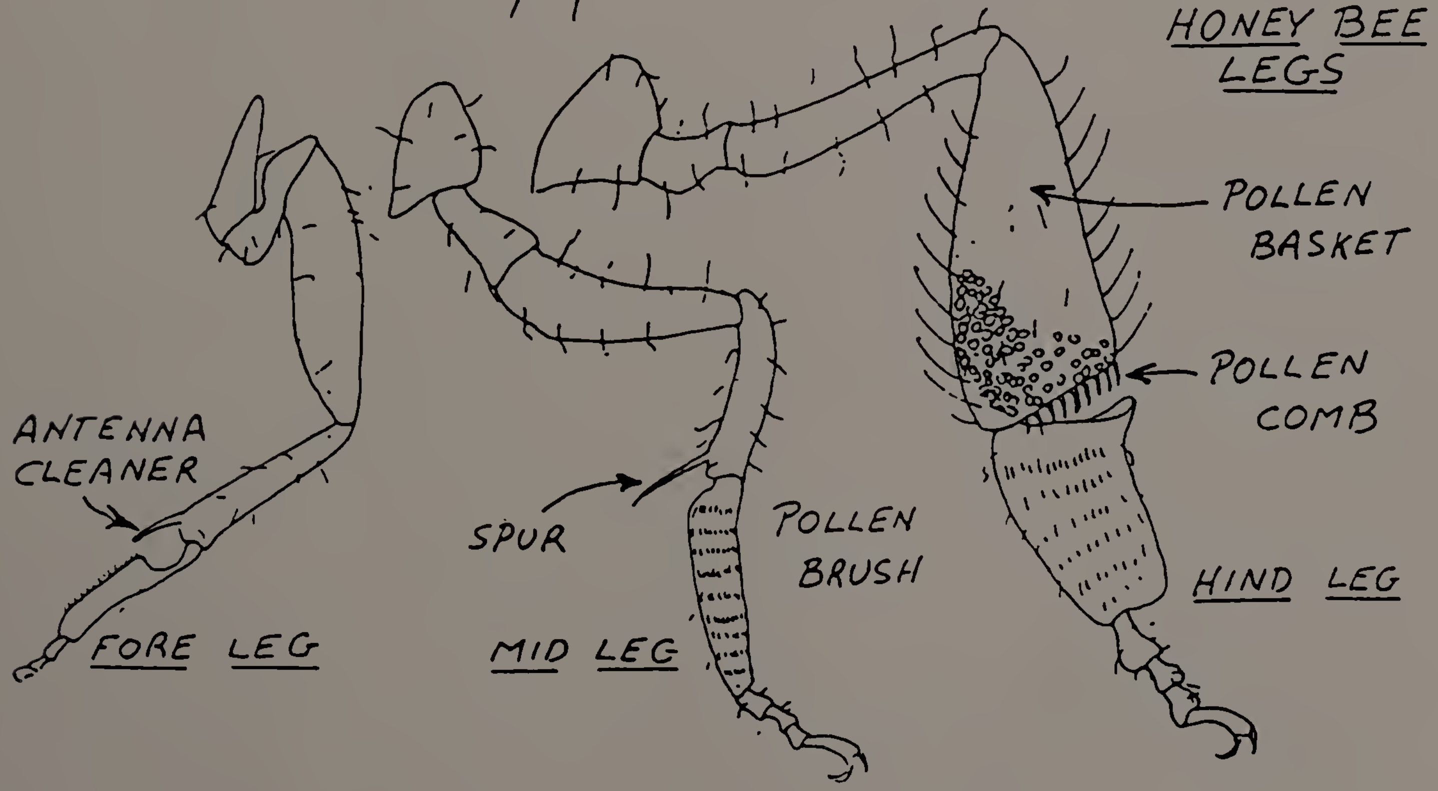
STICK IN CUP OVERNIGHT

REMOVE WINGS AND LEGS AND POLLINATE

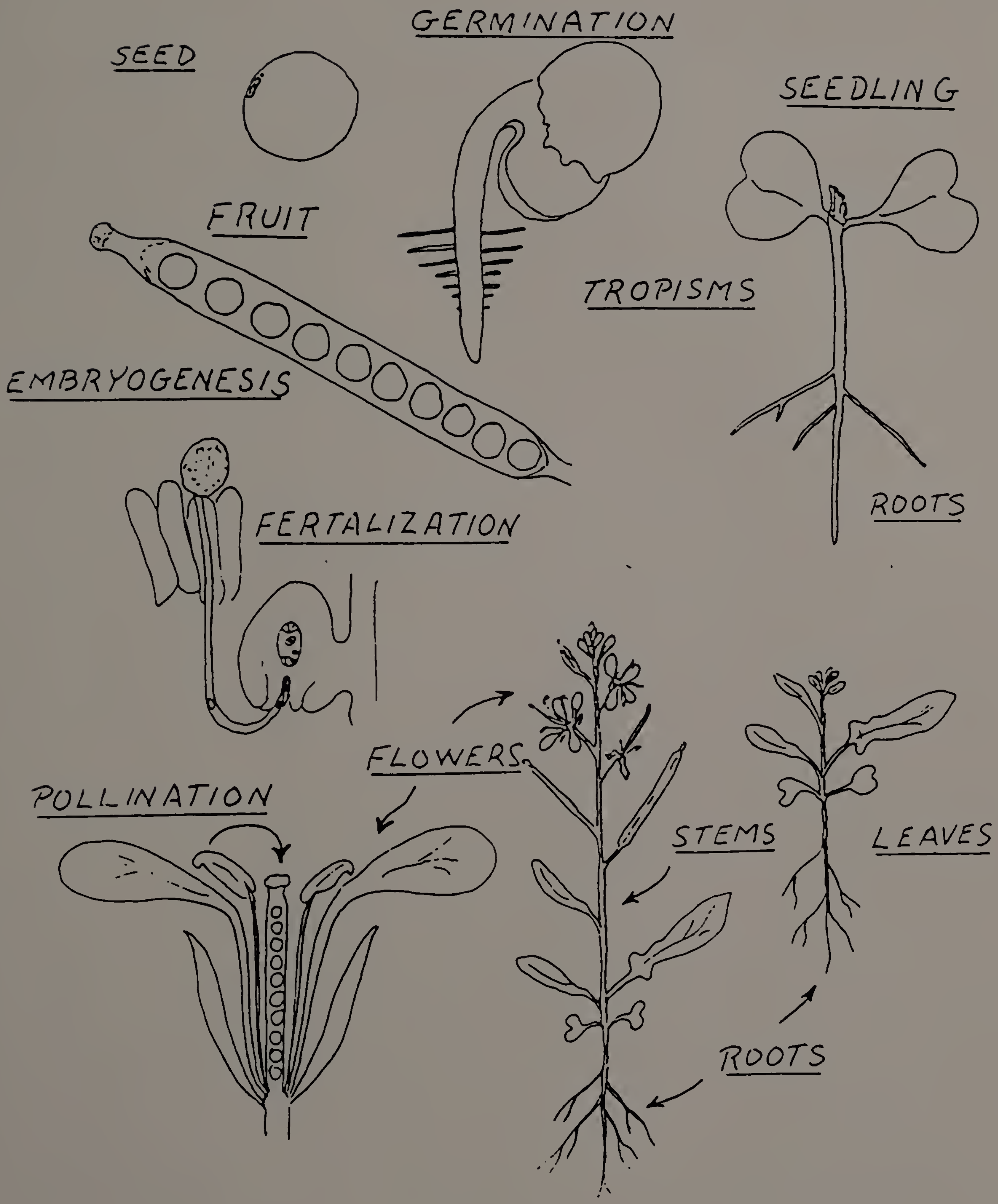
THE BRASSICA FLOWER



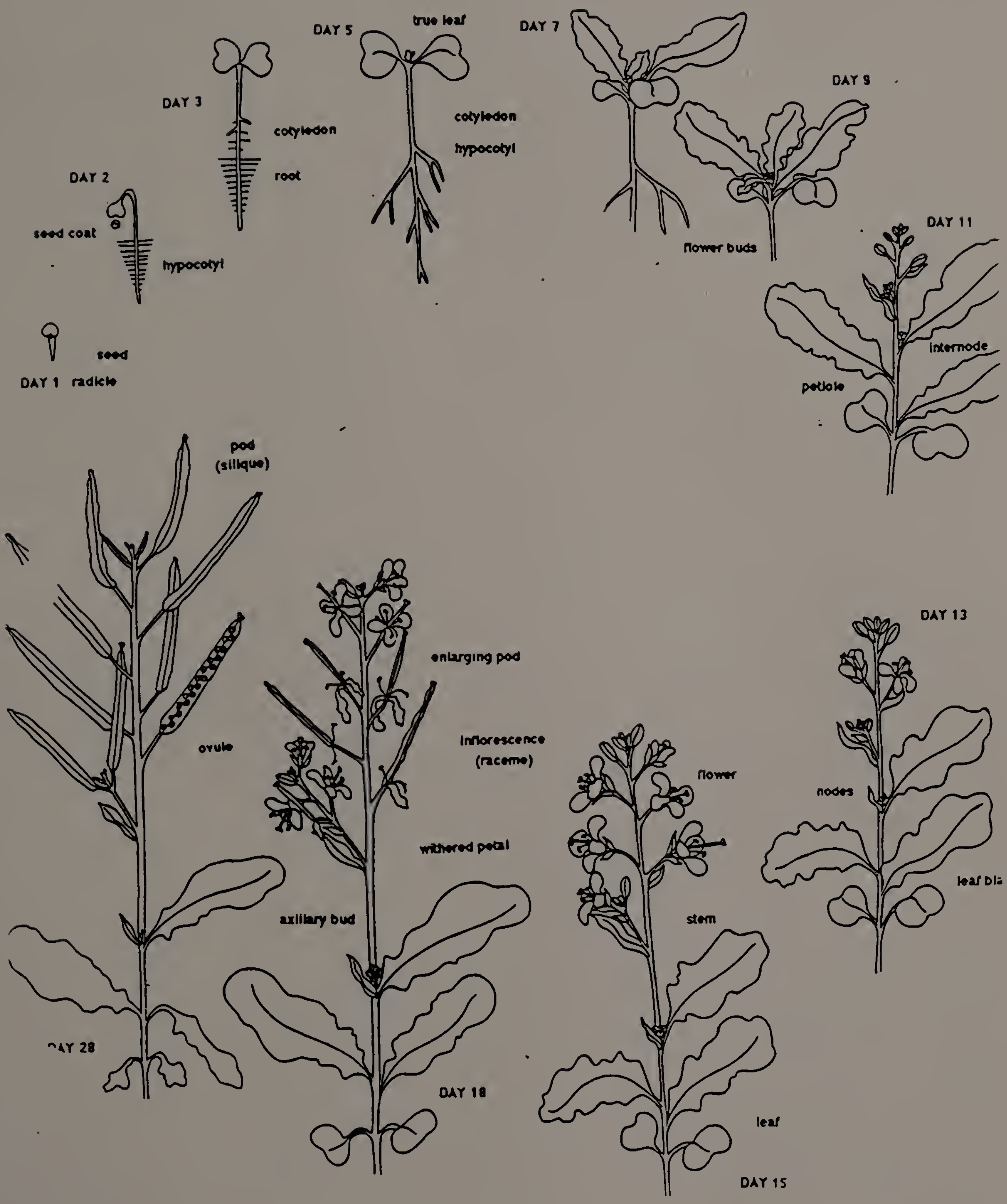

BRASSICA FLOWER
ANTHER (POLLEN)
BEE THORAX (HAIRY)
HONEY BEE
STIGMA
BEE ABDOMEN (HAIRY)
NECTAR
NECTARY
BEE PROBOSCIS (SIPPING NECTAR)


HONEY BEE LEGS
POLLEN BASKET
POLLEN COMB
ANTENNA CLEANER
SPUR
POLLEN BRUSH
HIND LEG
FORE LEG
MID LEG

GROWTH, DEVELOPMENT AND REPRODUCTION



LIFE CYCLE OF FAST PLANTS



FAST PLANT ACTIVITIES

Fast Plants can be used for the following topics:

1. Growth and Development
    - a. Growth: seed germination (plants up in 2 days), leaf formation, stem elongation, flowering (14-16 days), fruit (pod) and seed (embryogenesis), maturation.
    - b. Growth responses
    - c. Devlopment; morphology, root stem, leaf, flower.

2. Reproductive Biology
    - a. Flower development, male and female parts of flower
    - b. Pollen and pollination; control of pollination, bee sticks
    - c. Fertilization
    - d. Embryogenesis

3. Genetics; Mendelian and Nonmendelian
    - a. Mendelian; gene expression, dominance, interaction
    - b. Mendelian; gene assortment, independence, linkage, F1, F2 test cross
    - c. Nonmendelian; maternal inheritance
    - d. Nonmendelian; continuous variation, quantitative genetics
    - e. Selection
    - f. Evolution

4. Physiology; underlying mechanisms of growth and development
    - a. Using numerous physiological mutants
    - b. Growth hormone responders
    - c. Photosynthesis; randiant energy utilization
    - d. Nutrition; effects of major and minor elements on growth and reproduction
    - e. Water relations; excesses and deficiencies
    - f. Photoresponses; light intensity, photo period and flowering, tropism, etc.

5. Ecology (the plant responding to its environemnt
    - a. Influences of acid rain on plant growth and development
    - b. Effects of air pollution (pollution senstiive mutant stocks)
    - c. Chemcials in the plant environment: salt injury, herbicide effects
    - d. Effects of pests and diseases on plants
    - e. Disease resistance; microbe plant interactions

ACTIVITY 1: Growth, Development and Reproduction

<u>Concepts Illustrated:</u> Plant growth is a progression of developmental stages, each specifically oriented in the plants' environment and culminating in sexual reproduction and seed production. Sexuality in plants, pollination and fertilization results in the initiation of a new generation.

Day 1	Plant and water seeds
Day 2	Plants have emerged-- observe cotyledons
Day 5	Observe true leaves
Day 7-8	Observe appearance of flower buds
Day 9	Place on plant on side (tropisms)
Day 10	Observe reorientation of plant upward (discussion of growth)
Day 12-17	Observe enlargement of flower buds and elongation of stems
Day 14-17	Observe flowers opening (discussion of flower parts) Pollination using bee sticks between flowers on the same plant and flowers on different plants (discussion of role of bees in pollination)
Day 18-35	Observe petal fall, seed pod elongation Dissect selected pods and observe seed development at 3-4 day intervals
Day 37	Withold watering, observe plants withering and seed turning brown
Day 40	Harvest seed, and take seed home and continue exploration

ACTIVITY 2: Investigation of Flower Structure

<u>Introduction</u>: Brassicas produce flowers in 14-17 days. Plants (6-8) per class) will provide each student with at least one flower.

1. The flowers are large enough to be manipulated by hand or with tweezers. A hand lens can be used to magnify the basic flower parts. The sepals, petals, stamen, and pistil can be easily counted.
2. Make a wet mount slide of one of the anthers. Observe the pollen sacs under both low and high power. No stain is necessary.
   NOTE: The pollen grain is too small to observe the formation of a pollen tube under high power. No higher magnification has been tried. This is an area that is open to experimentation. Also, because of the small size of the pistil, dissection of the ovary is extremely difficult.

ACTIVITY 3: Influence of Acid Rain on Plant Growth

Concept Illustrated:Students learn concepts of experimentation and hypothesis testing by growing plants treated with water of different acidity (pH).

1. Plant growth observed (as in Exercise 1) but students measure growth variables (e.g., leaf size, plant height, etc.) at interals and compare them with untreated control plants.
2. Pollinate plants to produce seed (if reproduction was to be a measureable parameter).
3. Average number of seeds harvested from each plant for each acidity treatment.
4. Graph seed weight or plant height data relative to the water acidity as a basis for discussion of the effects of chemicals in the environment.

ACTIVITY 4: Is More "Food" Better?

1. One lab partner counts out fertilizer pellets. (2,4,6,8, etc. to 18 pellets x 4 trials)
2. Another partner makes 10 pot labels numbered from 0,2,4,6,...18
3. Fill the holes in the flat to half-full with soil mix
4. Add the correct number of Osmocote pellets to each depression. (REMEMBER: Do not add any pellets to the first set of four holes. These are for the control plants.
5. Fill pots to rim with soil, plant seeds, cover with soil as per planting instructions
6. Put correct pot labels in one row along the side of the flat.
7. SEVERAL DAYS LATER -- Remove the weaker plant from each minipot. Transplant seedlings into empty pots if necessary.
8. From the day the plants emerge, measure the height of the plants daily.
9. At the end of each week, count the leaves on each plant for each treatment (0,2,4,6,....etc.)
10. This experiment can be concluded in two weeks.
11. Make a table to record daily data of height of plants and weekly data of number of leaves. Add a line to record the average.
12. At the end of the data collecting, graph results.

ACTIVITY 5: Mendelian Genetics

Concepts illustrated: This exercise emphasizes hypothesis formulation and testing by selecting stocks of appropriate phenotype and examing Mendelian principles of genetics through controlled crosses and analysis of progeny. Dominance, independent assortment, linkage and crossing over, hybrid vigor, etc. will be explored.

Students grow plants, make choices as to experimental crosses needed for hypothesis testing. They make controlled pollinations, harvest seed, grow out progeny, record segregation of phenotypes and evaluate their hypotheses using simple statistical methods.

ACTIVITY 6: Comparing Pollination Success of Bees and Houseflies

Background: Since both bees and houseflies are attracted to the flowers of *Brassica rapa*,the success of each in cross-pollinating these flowers (*B. rapa* does not ordinarily self-pollinate) will be measured by seed production. Flowers pollinated by "bee sticks" will be used as a "base number" of seeds.

1. Prepare 3 minipots, each with 30 seeds of wild *B. campestris* according to the planting directions, modifying directions by putting together minipots with 10 sections, 3 seeds to each section.
2. When seeds germinate, thin to 1 plant in each of the 10 sections.
3. When the flowers begin to open, cover each of the 3 minipots with a box made from window screen or transparent plastic, or some other design so that each isolated from the other.
4. Into one minipot unit, under cover, place 4 bees; into a second one, 4 flies; the flowers in the third one should be cross-pollinated by "bee sticks." Observe the behavior of the bees and flies as they move from flower to flower.
5. After 3 days remove the bees and flies. Let the plants develop until evidence of pollination is seen (pod elongation and swelling).
6. Terminalize the plants.
7. After 20 days, remove plants, let dry 3-4 days.
8. Open the seed pods and count the seed for each type of pollination.
9. Record the results.

ACTIVITY 7: Salt Pollution

Background: Salt is used for de-icing roads in many areas during the winter. Commonly, sodium chloride is used, mixed with sand or other abrasives. There is concern about the direct effect of the salt on cement raod surfaces and metal portions of cars. In addition salt can have detrimental effects on vegetation - as spray from the road, by building up in the soil or by entering the groundwater.

Salt can affect a variety of different plants in different ways. The purpose of this exercise is to observe the effects of different salt concentrations on germination and growth of Fast Plants.

1. Prepare and label six resevoirs. Fill two of them with plain tap water (these are the untreated controls to demonstrate noraml growth). Fill the other four with salt concentations of 0.02%, 0.2%, 2% and 5%.
2. Plant two tetrads according to Fast Plant growing instructions. Water each thoroughly with plain tap water.
3. Place one tetrad on a resevoir containing PLAIN WATER. Place the other tetrads on resevoirs containing the various salt solutions (0.02%, 0.2%, 2% and 5%)

FROM NOW ON ADD ONLY PLAIN TAP WATER TO THE RESEVOIRS, NO MORE SALT

4. Day 5-7: Count the total number of healthy green seedlings in each tetrad. Record the number along with the treatment the plants received. If seedlings started to grow but turned brown and wilted (or died) record the number of these separately.
5. Day 10-14: Measure the height of the plants and record the data according to the treatment the plants received.
6. Day 14-18: Record the number of plants that are blooming for each treatment.
7. Day 16-45: If you wish to pollinate your plants and determine whether salt affects seed production, follow the general growing instructions for pollination, seed ripening and harvest.

ACTIVITY 8: The Effects of a Virus on Plants

Introduction: The symptoms of viral infections can be observed in Fast Plants. Both turnip mosaic and cauliflower mosaic virus can be used to demonstrate the effects of a virus on plants. Brassica leaves (either turnip or cauliflower) infected with the virus exhibit severly mottled, brown-yellow spots.

1. Plant seed in tetrad per Fast Plant growing instructions.
2. On day 7-8, select 1-2 plants to be treated.
3. Remove virus-infected leaf from diseased plant (either turnip or cauliflower). Place leaf in mortar with phosphate buffer solution and rock polishing abrasive. Grind material with pestle until you obtain a homogenous solution.
4. Dip your finger in the mortar and rub the solution onto the leaves of the plants you have selected to infect with virus. Be sure to avoid touching the other two plants which are your controls.
5. Rub the phosphate buffer solution only on the control plants (no abrasive).
6. Record daily observations of the plants for the remainder of the life cycle.

ACTIVITY 9: Effects of Plant Hormones

Introduction: The plant hormones presently known may be divided into five groups. Auxins, gibberellins, and cytokinins stimulate cell division and growth. Abscisic acid and ethylene usually stimulate dormancy or aging. In this activity you will use gibberellin and abscisic acid.

1. Plant 2 cells of a tetrad with normal seed, 2 cells with rosette seed. You may want to sow rosette seed 2-3 days before the normal seed since it is slower to emerge.
2. Record plant height each day up to the tenth day. Record height in each cell separately. Remember to thin plants to 1 plant per cell at the fourth day after emerging.
3. At day 10, begin treatment with plant hormones. Select one normal and one rosette plant for treatment. The other two plants will serve as controls. Select the hormone to study and use cotton swabs to apply the hormone to all of the leaves of the treated plants. Use swabs and distilled water on the control plants. Continue to treat the plants again on days 11 and 12.

4. Continue recording plant height for the remainder of the plant cycle.

APPENDIX B

DATA COLLECTION INSTRUMENTS

Initial Teacher Questionnaire

Student Questionnaire, Year 1

Guidelines for Teacher Interview, Year 1

Classroom Observation Schedule

Teacher Questionnaire, Year 2

Teacher Questionnaire, Year 3

Final Teacher Questionnaire

INITIAL TEACHER QUESTIONNAIRE: YEAR 1

Name____________________________ School____________________
Address_________________________ Address___________________
________________________ ____________________
Home phone______________________ School phone______________

EDUCATION Undergraduate Degree: Major:

Graduate Degree(s): Major:

Courses taken which included plant topics (ie. botany, genetics, horticulture, physiology, etc.)

Do you have a garden? Did in the past?
Grow flowers? vegetables and fruit?
Do you have houseplants? Did in the past?
Do you grow plants in your classroom/lab? In past?

TEACHING		Number of years taught	
Subject	Grade	Teaching Currently	Taught in Past

What are the most important things you hope your students will gain from your science classes?

What do you see as your role in the classroom?

What do you believe are the most important concepts about plants that students should understand?

What teaching about plants do you currently do?
How do you use live plant materials in your teaching?

What do you like most about teaching about plants?

What do you like least about teaching about plants?

What do you think your students like most about plants?

What do you think your students like least about plants?

What difficulties, if any, have you had in using plant materials in your classroom in the past?

How do you plan to use FAST PLANTS?

When during the year do you plan to use FAST PLANTS?

Is there anything in particular you are hoping to gain from the project?

What school and curriculum pressures, if any, will affect how you think you will be able to use FAST PLANTS?

What problems, if any, do you anticipate with FAST PLANTS?

Would you like to have a letter sent to anyone in your school system describing the project and your involvement

Comments/Questions:

STUDENT QUESTIONNAIRE: YEAR 1

Please complete following your FAST PLANT studies:

WHICH DO YOU PREFER TO STUDY? ANIMALS _____ PLANTS ______

1. How well did you like FAST PLANTS?
   not at all___they were o.k.___I really like them____

   Anything you especially liked?

2. Had you ever grown a plant from seed before, cared for it throughout its full life cycle, and collected seed from the plant? yes____ no____

3. What did you do with Fast Plants? What did you try to find out?

4. How well did your experiment work?
   terrible ____ not bad ____
   well ____ very well ____

5. What kinds of problems did you have?

6. What would you do differently if you conducted the experiment again?

7. What did you learn from working with FAST PLANTS?

8. Would you like to grow and study more plants?

GUIDELINES FOR TEACHER INTERVIEW

YEAR 1

This inquiry is being made to assess the usefulness of a new plant material, Wisconsin FAST PLANTS. Since the study is focused through the teacher's eyes, I wish to find out your opinions about the experience.

HUMAN SUBJECTS FORM

First I need you to read the human subjects form and sign it if you agree with the statement.

turn on tape recorder

EXPERIENCE WITH THE PLANTS:

Tell me about the teaching you do about plants with this class?

Make sure clear about:
---outline of plant topics taught this year.
---timeframe of teaching
---relationship to other topics

What texts do you use? Is your science curriculum prescribed or one you are free to set on your own?

Can you tell me more about how you used FAST PLANTS this year. (check questionnaire to see what teacher already has said)

Make sure get:
---with whom, when, how long?
---with another group after the first?
---what plant topics did you use Fast Plants for?
---what biological concepts did you teach?
---old activities adapted to Fast Plants or new activities?

Given what you have said about how you see your role in the classroom (check questionnaire) what would you say about the usefulness of FAST PLANTS to you in your teaching?

How would you compare your teaching about plants this year with the past? ---similarities ---differences

Did the amount of hands-on activities on part of students change? How?

What are your plans with FAST PLANTS for next year? (check questionnaire) ---similarities ---differences

Were there others who were interested in your work with FAST PLANTS? Can you tell me about it.

PROBLEMS AND OPPORTUNITIES

What sorts of problems, if any, did you encounter with the material? How did you solve those problems?
---changes ---adaptations

What new opportunities did the materials present to you? What could you do that you couldn't do before?

What sorts of supports, if any, might be useful to you (for example: more specific activities, slides, videotapes, newsletters, workshops, etc.)

STUDENT INTEREST AND LEARNING

What effect did Fast Plants have on your students interest in studying plants? Did they seem to be more or less interested than other students in the past?

Did your students enjoy working with the plants? What do you think they liked the most? the least?

What do you think your students learned? Was it valuable?
  Did student understandings of basic biological concepts increase?
  Were there things you thought they would learn that they didn't?
  Can you tell me about anything your students learned that you did not anticipate?

Did using Fast Plants encourage your students to ask "what if" questions?
  Show list of science process skills (observing, interpreting, hypothesizing, raising questions, planning investigations, recording, measuring, critical reflection)

  Did your students develop their abilities to use problem solving skills and any of this particular list of science process skills?

  Did you do more, the same or less hands-on activities?

TEACHER INTEREST AND LEARNING

Any comments about how using these plants affected your own professional and personal development?
  ---attitudes toward: ---plants ---teaching
  ---learning ---students

Did using Fast Plants increase your interest in learning more about plants? in teaching more about plants?

Did using Fast Plants stimulate your own creativity as a teacher?

Would you have preferred to have had more specific lessons plants, a syllabus, or more specific lab exercise type lessons?

CLASSROOM OBSERVATION SCHEDULE

Date

Teacher School
Grade/Subject # Students (m)
(f)

I. CLASSROOM

Student seating: alone whole class
single sex pairs mixed sex pairs
single sex groups mixed sex groups

Comments on classroom:

Classroom plan (draw on back of sheet):

II. <u>LESSON</u>

Topic of lesson:

<u>Lesson Outline</u>	<u>Teacher Doing?</u>	<u>Students Doing?</u>

Teaching materials/equipment/resources:

Objectives of lesson:

Objectives met?

Objectives stated? clear to students?

Objectives appropriate?

Other comments on lesson:

III. TEACHER

Comments

-- teaching technique/skills
-- organizational skills
-- questioning skills
-- clarity of explanation/instructions
-- response to student work
-- response to student behavior
-- teacher/student interactions
-- teacher/student talk

Teacher comments after lesson:

IV. STUDENTS

Comments

--interest in lesson
--what learned?
    intended or unintended
--student/student interactions
--student/student talk
--response to teacher
--student questions asked
--use of process skills:
    observation   hypothesizing   interpreting
    raising questions   planning   measuring
    recording   critical reflection

Interviews with individual students:

TEACHER QUESTIONNAIRE: YEAR 2

Name   School

I will not _____ use Fast Plants this year because:

- _____ not teaching biology/life science this year
- _____ not teaching any plant topics this year
- _____ no time in schedule this year
- _____ Fast Plants not as successful as I had hoped
- _____ no money in school budget for materials
- _____ a colleague will be using Fast Plants instead
- _____ kids did not learn what I had hoped
- _____ other: ____

Teaching about plants:
more____same____less____time this year
Fast Plants use: more____same____less____ time this year

Will use Fast Plants with the following topics:

- _____ growth and development/ life cycle
- _____ plant parts -- ie. roots, stem, flowers, etc.
- _____ plant reporduction
- _____ genetics
- _____ tropisms/plant hormones
- _____ ecology - plant/environment interaction
- _____ nutrition
- _____ photosynthesis/effects of light
- _____ evolution
- _____ other:

I will use Fast Plants with 1 2 3 4 5 classes

Other teachers in school system will use Fast Plants this year. Yes___ No___

This year I will____will not____give Fast Plant workshops
I am interested in learning more about plants and new approaches to teaching about plants: Yes__Maybe__No__

Fast Plants:

- _____ Give kids a chance to work like scientists in class
- _____ Kids have opportunity to raise their own questions and figure out ways to answer them.
- _____ Provide students with the opportunity to design their own investigations
- _____ Give students a chance to collect, record, and analyze data
- _____ Help students improve their attitudes toward science.
- _____ Are fun for the students
- _____ Are fun for me
- _____ Are easy to maintain in the classroom
- _____ Are inexpensive
- _____ I am learning as much as the students
- _____ Other:

TEACHER QUESTIONNAIRE: YEAR 3

Name

School

I will not _____ use Fast Plants this year because:
- _____ not teaching biology/life science this year
- _____ not teaching any plant topics this year
- _____ no time in schedule this year
- _____ Fast Plants not as successful as I had hoped
- _____ no money in school budget for materials
- _____ a colleague will be using Fast Plants instead
- _____ kids did not learn what I had hoped
- _____ other: ____

I will teach about plants more___same___less___this year
I will use Fast Plants more____same____less____this year

Fast Plants used for the following topics:
- _____ growth and development/ life cycle
- _____ plant parts -- ie. roots, stem, flowers, etc.
- _____ plant reporduction
- _____ genetics
- _____ tropisms/plant hormones
- _____ ecology - plant/environment interaction
- _____ nutrition
- _____ photosynthesis/effects of light
- _____ evolution
- _____ other:

I will use Fast Plants with 1 2 3 4 5 classes

Other teachers in my school system will use Fast Plants this year. Yes___ No___

I will____will not____ give Fast Plant workshops this year. # will give______

Fast Plant use last year:
- What did you do with them?
- Who did you use them with?
- Did you have any new problems?
- What was especially successful?
- What did not work?
- What changes do you plan for next year?

Circle the response that most accurately reflects your opinion:

1	Strong agreement	2	Agreement
3	Neutral	4	Disagreement
5	Strong disagreement	6	No opinion

Fast Plants give students a chance to:

to work like scientists in class	1	2	3	4	5	6
to design their own investigations	1	2	3	4	5	6
collect, record, and analyze data	1	2	3	4	5	6
raise their own questions & answer them	1	2	3	4	5	6

Fast Plants:

help students improve attitudes toward science	1	2	3	4	5	6
are fun for the students	1	2	3	4	5	6
are fun for me	1	2	3	4	5	6
are easy to maintain	1	2	3	4	5	6
are inexpensive	1	2	3	4	5	6
I am learning as much as the students	1	2	3	4	5	6

Other comments about Fast Plants:

FINAL TEACHER QUESTIONNAIRE

NAME ________________________________ PHONE__________

TEACHING BACKGROUND

Subjects taught	87-88	88-89	89-90
Life science			
Physical science			
Biology (college)			
Biology (honors)			
Biology (basic)			
Biology (AP)			
Biology II			
Chemistry			
__________________			
__________________			
__________________			

What aspects of biology/life science interest you most?

What aspects of biology/life science most difficult for you to teach?

What do you like to teach most?

What aspects of biology/life science are most interesting to your students?

What aspects most difficult for your students?

What do your students like to do the most in class?

Does your school have a specific curriculum?
Prescribed topics that you are expected to follow?

Where do you get most of your ideas about what to teach and how to teach?

Do you use a textbook? YES___NO___ NAME:
Do you like it? YES___NO___ Comments:
Do you?
follow the text closely? YES___NO___
start beginning/go to end? YES___NO___
teach entire book? YES___NO___

Parts left out:
use as reference only? YES___NO___

1=never 2=rarely 3=sometimes 4=often 5=always					
use lab exercises	1	2	3	4	5
students read text	1	2	3	4	5
homework assigned from text	1	2	3	4	5
use textbook tests	1	2	3	4	5

In your classes what percentage of time (on the average) is spent on:

lecture ________%
class discussion ________%
hands-on/lab activities ________%
individual research projects ________%
reading (independent/group) ________%
worksheets ________%
cooperative groups work ________%
computer work ________%
other ____________________ ________%

Has this changed in any substantial ways over the last 3 years? Describe

Do you plan to change you teaching methods in any major way in the near future? Describe

What other new curricula, teaching materials, pedagogical approaches or new programs have you been involved in:

(1987-88) ______________________________
(1988-89) ______________________________
(1989-90) ______________________________

What is the level of support and assistance offered to you by other teachers and administrators in what you are doing? ______________________________

1=none 2=very little 3=some 4=quite a lot 5=great deal

By other teachers in department? 1 2 3 4 5
By department chairman? 1 2 3 4 5
By school principal/administration? 1 2 3 4 5
By school system administration? 1 2 3 4 5

TEACHING ABOUT PLANTS

What do you want your students to learn about plants?

Approximate # days of plant studies: 1987-88________ 88-89_______ 89-90_______

What living materials do you use in you teaching about plants?

Interested in attending summer institutes on plants sometime in the future? YES ___ PERHAPS ___ NO ___

PLANT TOPICS TAUGHT:	1987-88	1988-89	1989-90
Plant Classification			
Algae			
Mosses, ferns			
Seed Plants			
Structure (seeds)			

Structure (roots)
Structure (stems)
Structure (leaves)
Structure (flowers)
Growth and Development
Life Cycle
Germination
Plant Nutrition
Plant Tropisms
Photosynthesis
Respiration
Transpiration
Reproduction
Genetics
Use of Plants in the World
World Food Production
Plant Ecology
Energy Source (CO2 cycle)
Growing & Caring for Plants
Insect/Plant Relationships
Flower Dissection
Independent Research
Problem Solving Skills

How much do the following restrict your teaching about plants?

1=none 2=very little 3=some 4=quite a lot 5=great deal

Important to keep in step with other teachers	1	2	3	4	5
Required to teach in specific order	1	2	3	4	5
Too many science topics to teach	1	2	3	4	5
Text book limits time can spend on plants	1	2	3	4	5
Curriculum requires teaching specific topics	1	2	3	4	5
Teacher interest less in plants than other topics	1	2	3	4	5
Students interest less in plants than other topics	1	2	3	4	5
Plants less important than other topics	1	2	3	4	5
Students already know a great deal about plants	1	2	3	4	5
Little you can do with plants in classroom	1	2	3	4	5
Must move from classroom to classroom	1	2	3	4	5
Little time to prepare for teaching	1	2	3	4	5
Little time to prepare for science labs	1	2	3	4	5
Inadequate lab facilities	1	2	3	4	5
Inadequate funding for lab materials	1	2	3	4	5
Preparing students for College Board Exams	1	2	3	4	5

Do you think there is an imbalance between the emphasis on plants and animals in science teaching? YES___ NO___

Do you teach MORE___LESS___SAME___amount about plants as others in school?

Next year do you intend to teach about plants:
MORE___LESS___SAME___

USING FAST PLANTS

Did you use Fast Plants this year (1989-90)? YES__NO__
REASON FOR NON-USE:

I used Fast Plants with the following classes:

Subject	Level	# classes 1987-1988	# classes 1988-1989	# classes 1989-1990

Were your intentions different than what you actually did? How and why?

What do you think your students have learned from using Fast Plants?

What do you think is best about Fast Plants?

Problems (Plants):	1987-88	1988-89	1989-90
death			
germination			
pollination			
seed production			
growth rate			
seed viability			
__________________			
Problems (Equipment):			
lights			
wicks			
water mats			
soil			
pots (tetrads)			

1=great increase 2=increase 3=no change
4=decrease 5=great increase 6=don't know

Since using Fast Plants:

time spent on plant study	1	2	3	4	5	6
time spent doing work	1	2	3	4	5	6
# of plant topics covered	1	2	3	4	5	6
my interest in teaching about plants	1	2	3	4	5	6
my interest in learning about plants	1	2	3	4	5	6
time spent doing rigorous experimental work by students	1	2	3	4	5	6

my interest/experimenting with plants	1	2	3	4	5	6
student interest in plant study	1	2	3	4	5	6
student understandings about plants	1	2	3	4	5	6
student interest/experimenting with plants	1	2	3	4	5	6
student practical understanding about plants needs	1	2	3	4	5	6
student interest in raising plants and/or in gardening	1	2	3	4	5	6
student "in-depth" learning about specific plant topics	1	2	3	4	5	6
student use of imagination & personal iniative in learning	1	2	3	4	5	6
student learning by "discovery"	1	2	3	4	5	6
# new lessons developed/plant topics	1	2	3	4	5	6
# new labs developed/plant topics	1	2	3	4	5	6

How easy was it to fit Fast Plants into your existing curriculum? VERY____SOMEWHAT____SO-SO____
SOMEWHAT DIFFICULT____VERY DIFFICULT____
Any change through time?

How closely do Fast Plants relate to your students natural

innate interests? VERY____SOMEWHAT____SO-SO____
NOT TOO MUCH____NOT AT ALL____

Since using Fast Plants have your teaching methodologies changed? VERY MUCH____SOME____NOT MUCH____NONE____

What about plants do you hope your students will retain after the details of what learned from your class have been forgotten?

Did Fast Plants help in any way? Describe.

1=strongly agree 2=agree 3=neutral
4=disagree 5=strongly disagree

Fast Plants:

Are fun for me as the teacher	1	2	3	4	5
Are fun for students	1	2	3	4	5
Are easy to care for	1	2	3	4	5
Are easy to grow	1	2	3	4	5
Increase student learning	1	2	3	4	5
Are useful for many different topics	1	2	3	4	5
Are useful for students/different ages	1	2	3	4	5
Are useful for students/different abilities	1	2	3	4	5
Can be used over again in different ways	1	2	3	4	5
Are accessible (previous learning not essential or necessary)	1	2	3	4	5
Helped me to become a more creative teacher	1	2	3	4	5
Helped me develop more imaginative lessons	1	2	3	4	5
Helped me grow professionally	1	2	3	4	5

Helped me learn more about plants	1	2	3	4	5
Increased my interest in learning more about plants in the future	1	2	3	4	5
Allows me to teacher certain topics in greater depth	1	2	3	4	5
What topics?					
Helps me teach plants more efficiently	1	2	3	4	5
Helps me develop better labs	1	2	3	4	5
Helps me be a better teacher	1	2	3	4	5
Caused me to increase amount of time spent teaching about plants	1	2	3	4	5
%increase: 1987-88_____1988-89_____1989-90_____					
Are easier to maintain than other plants	1	2	3	4	5
Are more fun for students than other plant activities	1	2	3	4	5

Any evidence of differences in retention of learning between students who used Fast Plants and those who didn't? Describe.

Any evidence of student change in attitude toward the study of plants after they worked with Fast Plants?
Describe.

Any evidence of student change in attitude toward science in general since they worked with Fast Plants?
Describe.

Describe any differences in student response to Fast Plants during the second year (1988-89)
third year (1989-90)

What other activities/investigations with Fast Plants do you want to try in the future? How likely is it that you will try the activity next year?

When your students were working with Fast Plants how frequently did they use the following science process skills during the past three years?

1=very often 2=often 3=sometime 4=rarely 5=never

Observation	1	2	3	4	5
Raising Questions	1	2	3	4	5
Measuring	1	2	3	4	5
Recording	1	2	3	4	5
(Graphing Results)	1	2	3	4	5
Hypothesizing	1	2	3	4	5
Interpreting	1	2	3	4	5
Planning Investigations	1	2	3	4	5
Critical Reflection	1	2	3	4	5

Have you told others about Fast Plants?
YES___ NO___ How many? _________

Others in your school using Fast Plants? YES___ NO___
How many? (1987-88)___ (1988-89)___ (1989-90)___

Others in your school system using them? YES___ NO___
How many? (1987-88)___ (1988-89)___ (1989-90)___

Did they begin using them because of you? YES___ NO___
Have your given any Fast Plant workshops? YES___ NO___
How many? (1987-88)___ (1988-89)___ (1989-90)___

Plan to give any other workshops this year? YES___NO___
How many? _____
Next year? YES___NO___ How many? ____

Fast Plant newsletters useful? YES___NO___
Any other comments:

APPENDIX C: WRITTEN CONSENT FORM

To participants in this study:

I am Judith Fischer, a graduate student at the University of Massachusetts, in Amherst. The subject of my doctoral research is "Fast Plants." As part of this study, I am interviewing approximately twenty New England teachers, who are piloting the material in their classrooms, about their experiences using this new plant cultivar.

The goal of this study is to assess the usefulness to classroom teachers of this plant developed for biological research. Analysis will be made of data gathered from questionnaires, classsroom visits, and interviews in order to better understand the experiences of those who used this new material. It is hoped that this inquiry will be valuable to other teachers, to those interested in curriculum and staff development, and to other researchers.

I am interested in the concrete details of your professional experience as a classroom teacher; what your day to day experience using this new innovation with your students has been, and what it means to you. As part of my dissertation, I may include materials from your interviews as documentation. Each interview will be audiotaped for later reference with initials for names. In all written materials and oral presentations in which I might use material from your interview I will use neither your name, names of your students, or the name of your school, city, or town. If I wish to use any materials in any way not consistent with what is stated above, I would ask for your additional written consent.

You may at any time withdraw from the researach project. In signing the form you will be assuring me that you understand the purpose of this study and the use to which these materials will be put. You are also assuring me that you will make no financial claims for the use of the material, and that no medical treatment will be required by you from the University of Massachusetts should any physical injury result from participating in this study.

I, ____, have read the above statement, and agree to participate in the study under the conditions stated therein.

____

Signature of participant   Date

BIBLIOGRAPHY

Adams, J. W., & Attridge, T. H. (1984). Plant responses to shade. Journal of Biological Education, 18(3), 181-184.

Adler, M. J. (1982). The Paideia proposal. New York: Macmillan.

Aicken, Frederick (1984), The nature of science. London: Heinemann

American Association for the Advancement of Science (1989). Science for All Americans. Washington: Author.

Anderson, C. W. (1987). Strategic teaching in science. In B.F. Jones, A.S. Palincsar & E. G. Carr (Eds.), Strategic teaching and learning: Cognitive instruction in the content areas. Alexandria: ASCD.

Anderson, C. W. & Smith, E. L. (1987). Teaching science. In V. Koehler (Ed.), The educator's handbook: A research perspective. New York: Longman.

Ashton-Warner, S. (1963). Teacher. New York: Simon & Schuster.

Aston, T. J. (1987). Plant-pollinator interactions, a rich area for study. Journal of Biological Education, 21(4), 267-274.

Baez, A. V., Knamiller G. W., & Smyth, J. C. (Eds.) (1987). The environment and science and technology education. Oxford: Pergamon.

Barker, M. & Carr, M. (1989). Photosynthesis--can our pupils see the wood for the trees? Journal of Biological Education, 23(1), 41-44.

Barnes, D. (1987). From communication to curriculum. New York: Viking Penguin.

Barrass, R. (1984). Misconceptions and misunderstanding perpetuated by teachers and textbooks of biology. Journal of Biological Education, 18(3), 201-206.

Barufaldi, J. P., Ladd, G. T., & Moses, A. J. (1984). Science. Lexington, MA: D. C. Heath.

Bell, B. F. (1981). What is a plant; some children's ideas. New Zealand Science Teacher, 31, 10-14.

Bell, B. F. (1985a). The construction of meaning and conceptual change in classroom settings: Case studies on plant nutrition (Children's Learning in Science Project). Leeds, England: University of Leeds, Centre for Studies in Science and Mathematics Education.

Bell, B. F. (1985b). Students' ideas about plant nutrition: what are they? Journal of Biological Education, 19(3), 213-218.

Bernhardt, P. (1989) Wily violets and underground orchids: Revelations of a botanist. New York: Random House.

Bicak, C. (1986). The role of water in germination. Journal of College Science Teaching, 16(1), 35-37.

Biddulph, F. (1984). Pupils' ideas about flowering plants (Learning in Science Project Working Paper No. 125). Hamilton, New Zealand: Waikato University, Science Education Research Unit. (ERIC Document Reproduction Service No. ED 252 406).

Bishop, Beth A. (1986). Respiration and photosynthesis: A teaching module (Occasional Paper No. 90). East Lansing: Michigan State University, East Lansing Institute for Research on Teaching (ERIC Document Reproduction Service No. ED 272 382).

Blum, A., & Silberstein, M. (1979). Trends in biological education in Israel. Journal of Biological Education, 13(1), 41-51.

Bogden, R., & Biklen, S. (1982). Quantitative research for education. Boston: Allyn & Bacon.

Bookman, P. A. (1989). And outdoor lab exercise using leaf traps. The American Biology Teacher. 51(7), 432-435.

Borg, W. R. & Gall, M. D. (1983). Educational research: An Introduction (4th ed.). New York: Longman.

Boyer, E. L. (1983). High school: A report on secondary education in America. New York: Harper & Row.

British Museum (Natural History) (1982). Nature at work. Cambridge: Cambridge University Press.

Britten, J. (1970). Language and Learning. London: Penguin.

Brooks, M., & Hounshell, P. B. (1975). A study of locus control and science achievement. Journal of Research in Science Teaching, 12, 175-181.

Brown, L. (1976). Weeds in winter. New York: Norton.

Bruner, Jerome. (1963). The Process of education. New York: Vintage.

Bundy, M. R. (1983). See how they grow. Science and Children, 21(2), 42-43.

Business-Higher Education Forum. (1983). America's competitve challenge: The need for a national response. Washington: The Forum.

Carnegie Forum on Education and the Economy, Task Force on Teaching as a Profession. (1986). A nation prepared: Teachers for the 21st century. New York: The Forum.

Carrick, T. (1983). Some biology teachers goals in advanced level teaching. Journal of Biological Education, 17(3), 205-214.

Champagne, A. B. (Ed.). (1988). Science teaching: Making the system work. Washington: American Association for the Advancement of Science.

Clark, M. (1989). Biological and health sciences: Report of the project 2061 phase I biological and health sciences panel. Washington: American Association for the Advancement of Science.

Clay-Poole, S. T., & Sleanick, I. L. (1983). The beauty of biology of pollen. The American Biology Teacher, 45(7), 366-370.

Cobb, B. (1963). A field guide to the ferns. Boston: Houghton Mifflin.

Cohn, M. et al. (1987). Teachers' perspectives on the problems of their profession: Implications for policymakers and practitioners (Contract #H-ERI-D-86-3090). Washington: Department of Education, Office of Educational Research.

Comstock, A. B. (1986). Handbook of nature study. Ithaca, NY: Comstock Publishing Associates. (Original work published in 1911).

Cook, T. D. & Campbell, D. T. (1976). The design and conduct of quasi-experiments and true experiments in field settings. In M. D. Dunnette, (Ed.), Handbook of industrial and organizational psychology. Chicago: Rand McNally.

Cremin, Lawrence A. (1962). The transformation of the school: Progressivism in American education. New York: Knopf.

Cronbach, L. J. (1975). Beyond the two disciplines of scientific psychology. American Psychologist, 30, 116-127.

Daniel, L., Kaskel, A., & Siegel, B. (1987). Focus on life science. New York: Merrill.

Dawson, C. J. (1983). What science do pupils prefer? A study of some South Australian twelve year olds. School Science Review, 65(230), 133-136.

Demchik, M. J. (1989). Investigating a population of dandelions on a school lawn. The American Biology Teacher, 51(4), 236-238.

Dempsey, A. D. (1990). Van Helmont's tree revisited. Science and Children, 27(6), 18-19.

Devonald, V. G. (1986). Project work with plant roots. Journal of Biological Education, 20(1), 33-36.

DeYoung, H. G. (1983). Crop genetics: The seeds of revolution. High Technology, 3(6), 53-59.

Driver, R., Guesne, E., & Tiberghien, A. (Eds.). Children's ideas in science. Milton Keynes, England: Open University Press.

Driver, R. (1985). The pupil as scientist? Milton Keynes, England: Open University Press.

Durrell, Gerald. (1986). A practical guide for the amateur naturalist. New York: Alfred A. Knopf.

Durrell, L. (1986). State of the ark. Garden City, NY: Doubleday.

Dworkin, Martin A. (1965). Dewey on education: Selections. New York: Teachers College Press.

Enochs, L. G., & Harty, H. (1983). Development of an inservice implementation proneness typology for science teachers. Science Education, 67(2), 143-150.

Eswaran, H., Kupelian, T., Levermann, T. & Yost, D. (1990). The science of soil. The Science Teacher, 57(5), 50-53.

Evans, M. L. (1986). How roots respond to gravity. Scientific American, 255(6), 112-119.

Exxon Education Foundation. (1984). Science education in the United States: Essential steps for achieving fundamental improvement. New York: The Foundation.

Flegg, J. (1985). Oakwatch: A seasonal guide to the natural history in and around the oak tree. London: Pelham.

Fosnot, C. T. (1989). Enquiring teachers, enquiring learners. New York: Teachers College Press.

Fraser, Barry J. & Cohen, David (1989). A retrospective account of the development and evaluation processes of a science curriculum project. Science Education, 73(1): 225-44.

Fullan, M. (1978). Implementing change in occupational education. Ithaca: Cornell Institute for Occupational Education.

Fullan, M. (1985). Curriculum implementation. In Husen, T., & Postelthwaite, T. N. (Eds.). International Encyclopedia of Education. Oxford: Pergamon, pp. 1208-1215.

Fullan, M., & Pomfret, A. (1977). Reserach on Curriculum and Instruction Implementation. Review of Educational Reserach, 47(1), 335-397.

Fuller, F. F. (1969). Concerns of teachers: A developmental conceptuatlization. American Educational Research Journal, (2), 207-226.

Furth, H. & Wachs, H. (1974). Thinking goes to school: Piaget's theory in practice. New York: Oxford University Press.

Fry, G. L. A., & Wratten, S. D. (1979). Insect-plant relationships in ecological teaching. Journal of Biological Education, 13(4), 267-274.

Galston, A.W. (1981). Green wisdom: The inside story of plant life. New York: Basic Books.

Gamble, R., Davey, A., Gott, R., & Welford, G. (1985). Science at age 15: A report on the findings of the age 15 APU science surveys. Hatfield, England: Association for Science Education.

Gardner, P. L. (1975). Attitudes to science: A review. Studies in Science Education, 2, 1-41.

Garner, M. (1987). Grow a garden in water. Science Activities, 24(3), 30-31.

Gayford, C. G. (1984). Water relations and the vacuolated plant cell: A brief study of the topic at the advanced level in school biology. Journal of Biological Education, 18(2), 151-155.

Gibbons, B. (1990). Missouri's garden of consequence. National Geographic. 178 (2), 124-140.

Gill, J. (1982). A study of germination inhibition in fruits. Journal of Biological Education, 16(3), 162-163.

Glimn-Lacy, J. & Kaufman, P. B. (1984). Botany illustrated. New York: Van Nostrand.

Goetz, J. P. & LeCompte, M. D. (1984). Ethnography and Qualitative design in educational research. Orlando: Acaademic Press.

Goodlad, J. I. (1983). A place called school: Prospects forthe future. New York: McGraw-Hill.

Gotsch, M. & Harris, Backyard Taxonomy. Science and Children. 27 (4), 25-27.

Green, J. (Ed). (1986). What next? More leverage for teachers. Denver: Educational Commission of the States.

Grinnell, F. (1987). The scientific attitude. Boulder: Westview.

Grow lab: A complete guide to gardening in the classroom. (1988). Burlington, VT: National Gardening Association.

Gwynn, M. L. (1988). A growing phenomenon. Science and Children, 25(7), 25-26.

Hafner, R.S. (1987). Brassica rapa: A resource book for secondary biology teachers. Unpublished master's thesis, University of Wisconsin-Madison.

Hafner, R.S. (1990). Fast Plants--Rapid Cycling Brassicas. The American Biology Teacher, 52 (1), 40-46.

Hall, G. E., & Loucks, S. F. (1977). A developmental model for determining whether the treatment is actually implemented. American Educational Research Journal, 14(3), 263-276.

Hall, G. E., & Loucks, S. (1978). Teacher concerns as a basis for facilitating and personalizing staff development. Teachers' College Record, 80(1), 36-54.

Hall, G. E., & Loucks, S. F. (1981). Program definition and adaptation: Implications for inservice. Journal of Research and Development in Education, 14, 46-58.

Hall, G. E., Loucks, S. F., Rutherford, W. L., & Newlove, B. W. (1975). Levels of use of the innovation: A framework for analyzing innovation adoption. Journal of Teacher Education, 26(1), 52-56.

Hammersley, M., & Atkinson, P. (1983). Ethnography: Principles in practice. New York: Tavistock.

Hanif, M. (1990). The vanishing bog. Science and Children. 27(7), 25-27.

Harlen, W. (1985). Teaching and learning primary science. New York: Teachers College Press.

Harlen, W. (1986). Creativity and rationality in learning and teaching science. Text of inaugural lecture given May 1, 1986, at the University of Liverpool. Liverpool: University of Liverpool Department of Education.

Harlen, W. (1987). What is going on in SPACE?. Liverpool: University of Liverpool, Centre for Research in Primary Science and Technology.

Harlen, W. & Jelly, S. (1989). Developing science in the primary classroom. Edinburgh: Oliver & Boyd.

Havelock, R. G. (1973). The change agent's guide to innovation in education. Englewood Cliffs, NJ: Educational Technology Publications.

Head, J. (1985). The personal response to science. Cambridge: Cambridge University Press.

Heck, S. F., & Williams, C. R. (1984). The complex roles of the teacher: An ecological perspective. New York: Teachers College Press.

Heller, R. (1983). The reason for a flower. New York: Grosset & Dunlap.

Hershey, D.R. (1990). Pardon me, but your roots are showing. The Science Teacher, 57(2), 42-45.

Hibbert, A. & Brooks, J. (1981). Plants in action: A scientific background to gardening. London: British Broadcasting Corporation.

Hitchcock, A. S. (1971). Manual of the grasses of the United States (2 Vols.) (rev. ed.). New York: Dover.

Hogan, K. (1990). Dissecting Flowers. Science and Children, 27(8), 15.

Holly, M. L., & Blackman, C. (1983). Building a conceptual framework for professional development. Action in Teacher Education, 391), 1-10.

Holmes Group. (1986). Tomorrow's teachers: A report of the Holmes Group. East Lansing, MI: The Group.

Honey, J. N. (1984). The use of polarized light in teaching plant anatomy. Journal of Biological Education, 18(1), 9-10.

Honey, J. N. (1987). Where have all the flowers gone: The place of plants in school science. Journal of Biological Education, 21(3), 185-189.

Hosford, P. L. (Ed.). (1984). Using what we know about teaching. Alexandria, VA: Association for Supervision and Curriculum Development.

Huxley, A. (1985). Green inheritance: The world wildlife fund book of plants. Garden City: Anchor/Doubleday.

International Association for the Evaluation of Educational Achievement. (1988). Science achievement in seventeen countries: A preliminary report. Oxford: Pergamon.

Jackson, P. W. (1968). Life in classrooms. New York: Holt, Rinehart & Winston.

John Henry Company (1976). How to care for 150 foliage plants. Lansing, MI: Author.

John Henry Company (1976). How to detect & solve plant problems. Lansing, MI:Author.

John Henry Company (1976). How to multiply your plants. Lansing, MI: Author.

John Henry Company (1976). How to reflower & care for 50 flowering plants. Lansing, MI: Author.

Johnson, D. W. & Johnson F. P. (1975). Joining together: Group theory and group skills. Englewood Cliffs, NJ: Prentice-Hall.

Johnson, D. W. & Johnson, R. T. Learning togher and alone: Cooperation, competition, and individualization. Englewood Cliffs, NJ: Prentice-Hall.

Johnson, M. & Stone, Judith (1989). The Great pumpkin. Science and Children, 27(1), 45-47.

Joyce, B. (1986). Improving America's schools. New York: Longman.

Jusaitis, M. (1985). A new system for studying adventitious root formation in cuttings. Journal of Biological Education, 19(3), 179-180.

Kallas, J. N. (1984). Wild Marshmallows. The Science Teacher, 51(5), 46-52.

Kamrin, A. A., & LaVan, J. S. (1984). Demonstrating osmosis and anthrocyanin using purple onion. The American Biology Teacher, 46(2), 116-117.

Karmer, D. C. (1983). Starting trees from cuttings. Science and Children, 21(3), 23-24.

Kelly, A., Smail, B., & Whyte, J. (1981). Girls into science and technology: Initial report. Manchester, England: University of Manchester, Department of Sociology/GIST.

Kemis, S. (1985). Action Reserach. In T. Husen & T. H. Postlewaite, International encyclopedia of education: Research studies. Oxford: Pergamon.

Kendler, B. S. (1989). Familiarizing students with some edible & poisonous wild plants. The American Biology Teacher, 51(8), 463-471.

Kendrick, R. E. (1981). How plants make light work of growth. Journal of Biological Education, 15(2), 85-89.

Kim, H. (1985). A winter sprout garden. Science and Children, 22(4), 21-22.

Klein, M. S. & Rutherford, F. J. (Eds.) (1985). Science education in global perspective: Lessons from five countries. Boulder, CO: Westview Press.

Klein, S. T. (1981). Why leaves turn color: A lab model for hypothesis formation. The American Biology Teacher, 17(2), 20-24.

Knapp, V., & Knapp, C. (1980). Getting acquainted with the dandelion. Science Activities, 17(2), 20-24.

Kohl, H. (1984). On becoming a teacher. New York: Harper & Row.

Kordan, H. A. In vivo effects of barbituates on seed germination and seed growth. Journal of Biological Education, 18(4), 266-268.

Kuhn, T. (1963). The structure of scientific revolutions. Chicago: Chicago U. Press.

Labinowicz. E. (1980). The Piaget primer: Thinking, learning, teaching. Menlo Park, CA: Addison Wesley.

Lester, N. B. & Onore, C. S. (1990). Learning change: One school distict meets language across the curriculum. Portsmouth, NH: Heinemann.

Lieberman, A. (Ed.). (1988). Building a professional culture in schools. New York: Teachers College Press.

Lieberman, A., & Miller, Lynne. (1984). Teachers, their world, and their work: Implications for school improvement. Alexandria, VA: Association for Supervision and Curriculum Development.

Little, E. L. (1980). The Audubon Society field guide to North American trees. New York: Knopf.

Little, J. (1986). Seductive images and organizational realities in professional development. In Lieberman, A. (Ed.). Rethinking School Improvement. New York: Teachers College Press.

Longnecker, N. E. (1981). Simplified method for observing mitosis. The American Biology Teacher, 43(3), 160.

Lortie, D. C. (1975). Schoolteacher: A sociological study. Chicago: University of Chicago Press.

Loucks, S. F., & Hayl, G. (1977). Assessing and facilitating the implementation of innovations: A new approach. Educational Technology, 5 (2), 18-21.

Loucks, S. F., & Sacchie, D. A. (1983). Applying our findings to today's innovations. Educational Leadership. November 1983, 28-31.

Loveless, A. R. (1984). Consider the grasses. Journal of Biological Education, 18(2), 156-160.

Macrorie, K. (1984). Twenty teachers. New York: Oxford University Press.

Maeroff, G. I. (1988). The empowerment of teachers: Overcoming the crisis of confidence. New York: Teachers College Press.

Maier, L. L. (1987). Flowers and classification. The Science Teacher, 54(5), 72.

Martin, F. L. (1979). The development of an instrument for determining botanically related misconceptions of beginning college botany students. Dissertation Abstracts International, 40. (University Microfilms No. 80-08,111).

Mason, D. H. (1982). Full of beans. Science and Children, 20(2), 16-17.

McKenney, M. & Peterson, R. T. (1959). A field guide to the wildflowers of the northeastern and central states. Boston: Houghton Mifflin.

McKie, M. E. (1984). Some plants we eat. Science and Children, 21(5), 19-20.

McLaughlin, M. R., Wallin, S., Pfeifer, D., Swanson-Owens, S., & Yee, J. (1986). Why teachers won't teach. Phi Delta Kappan, 67(6), 420-426.

Mechling, K. R., & Twiest, G. E. (1982). The amazing amaryllis. Science and Children, 19(5), 28-29.

Merzie, B. (1982). Ferocious flora. Science and Children, 20(3), 16-19.

Miller, J. W., & Ellsworth, R. (1983). Can we predict which teachers will benefit most from in-service programs? Teacher Educator, 19(2), 14-19.

Moffett, M. W. (1989). Life in a nutshell. National Geographic, 175(6), 783-796.

Mullis, I. V. S. & Jenkins, L. B. (1988). The science report card, elements of risk and discovery: Trends and achievement based on the 1986 national assessment. Princeton, NJ: Educational Testing Service.

Myers, N. (Ed.). (1984). GAIA: An atlas of planet management. Garden City, NY: Anchor Books.

National Commission on Excellence in Education. (1983). A nation at risk: The imperative for educational reform. Washington: U.S. Department of Education.

National Governors' Association. (1987). Making American work. Bringing down the Barriers. Productive people productive policies. Washington: The Association.

National Science Board Commission on Precollege Education in Mathematics, Science, and Technology. (1983). Educating Americans for the 21st century: A report to the American people and the national science board. Washington: National Science Foundation.

National Science Foundation and the U. S. Department of Education. (1980). Science and engineering education for the 1980's and beyond. Washington: The Foundation.

Nelson, C. J. (1988). Harvesting a curriculum. Science and Children, 25(7), 22-24.

Newcomb, L. (1977). Newcomb's wildflower guide. Boston: Little Brown.

Nichol, E. (1990). Hydroponics & aquaculture in the high school classroom. The American Biology Teacher, 52(3), 182-184.

Niering, W. A. & Olmstead, N. C. (1979). The Audubon Society field guide to North American wildflowers. New York: Knopf.

Nowak, N. (1984). Using weeds and wildflowers to study plants. Science Scope, 8(1), 12-13.

Ocone, L. & Pranis, E. (1983). The youth gardening book. Burlington, VT: National Gardening Association.

Okeke, E. A. C., & Wood-Robinson, C. (1980). A study of Nigerian pupils' understanding of selected biological concepts. Journal of Biological Education, 14(4), 329-338.

Osborne, R., & Freyberg, P. (1985). Learning in science: The implications of children's science. Portsmouth, NH: Heinemann.

O'Sullivan, F., Jones, K. & Reid, K. (1988). Staff development in secondary schools. London: Hodder & Stoughton.

Otto, J. H., & Towle, A. (1985). Modern biology. New York: Holt, Rinehart & Winston.

Oxlade, E. L. (1985). A simple plant growth analysis. Journal of Biological Education, 19(2), 131-136.

Oxlade, E. L., & Clifford, P. E. (1981). Experiments in geotropism. Journal of Biological Education, 15(2), 137-142.

Paley, V.G. (1979). White teacher. Cambridge: Harvard University Press.

Paley, V. G. (1981). Wally's stories. Cambridge: Harvard University Press.

Panel on Secondary School Education for the Changing Workplace. (1984). High schools and the changing workplace: The employers' view. Washington: National Academy Press.

Parker, L. H., & Rennie, L. J. (1986). Sex-stereotyped attitudes about science: Can they be changed? European Journal of Science Education, 8(2), 173-183.

Pesch, B. B. (Ed.). (1984). Gardening with children. Plants and Gardens, Booklyn Botanic Garden Record, 40(3).

Petrides, G. A. (1958). A field guide to trees and shrubs. Boston: Houghton Mifflin.

Pfundt, H. & Duit, R. (1988). Bibliography: Students' alternative frameworks and science education. Kiel, Germany: Institute for Science Education.

Piaget, J. & Inhelder, B. (1969). The psychology of the child. New York: Basic Books.

Platt, R. (1988). This green world. New York: Dodd, Mead. (Original work published 1942).

Polanyi, M. (1958). Personal knowledge. London: Routledge.

Popper, K. R. (1972). Objective knowledge. Oxford: Oxford University Press.

Powell, R. E. (1984). Going to Seed. Science and Children, 21(5), 21-23.

Rao, A. N., (Ed.). Food, agriculture and education. Oxford: Pergamon.

Repetto, R. (1990). Deforestation in the tropics. Scientific American, 262(4), 36-42.

Resource guide to educational materials about agriculture: A project of agriculture in the classroom. (1986). Washington: U.S. Department of Agriculture.

Rist, R. (1980) in a speech given at the University of Connecticut. Cited in Hosford, P. L. (Ed.), Using what we know about teaching. Alexandria, VA: Association for Supervision and Curriculum Development.

Rogers, E. M., & Shoemaker, F. F. (1971). Communication of innovations: A cross-cultural approach. New York: Free Press.

Rogers, Vincent R. (1984). Qualitative research--another way of knowing. In Hosford, Phillip L. (Ed.), Using what we know about teaching. Alexandria, VA: Association for Supervision and Curriculum Development.

Rosenblatt, R. (Ed.). (1990). Trees [Special Earth Day 1990 issue]. Life, (13)6.

Roth, C. E. (1984). The plant observer's guidebook: A field botany manual for the amateur naturalist. Englewood Cliffs, NJ: Prentice-Hall.

Roth, K. J. (1987). Should we worry about students' misconceptions in science teaching? Appraisal: Science Books for Young People, 20(3), 6-13.

Ruddock, J., & Kelly, P. (1976). The dissemination of curriculum development: Current trends (European Trend Report on Educational Reserach). London: National Foundation of Educational Research.

Rudduck, J., & Hopkins, David. (1985). Research as a basis for teaching: Readings from the work of Lawrence Stenhouse. Portsmouth, NH: Heinemann.

Rupp, R. (1987). Blue corn and square tomatoes: Unusual facts about common vegetables. Pownal, VT: Storey Communications.

Russell, T. & Watt, D. (1990). Growth (Primary Space Project Research Report). Liverpool: Liverpool University Press.

Sarason, S. B. (1982). The culture of the school and the problem of change (2nd ed.). Boston: Allyn & Bacon.

Scharmann, L. C. (1984). Autumn leaf chromotography. Science and Children. 22(1), 11-13.

Science report card: Elements of risk and recovery. (1988). (National Assessment of Educational Progress. Princeton: The Nation's Report Card.

Scientific literacy. [entire issue] (1983). Daedalus, 112(2).

Seymour, J. & Girardet, H. (1987). Blueprint for a green planet: Your practical guide to restoring the world's environment. New York: Prentice-Hall.

Simpson, M., & Arnold, B. (1982a). The inappropiriate use of subsumers in biology learning. European Journal of Science Education, 4(2), 173-183.

Simpson, M., & Arnold, B. (1982b). Availability of prerequisite concepts for learning biology at certificate level. Journal of Biological Education, 16(1), 65-72.

Sizer, T. S. (1984). Horace's compromise: The dilemma of the American high school. Boston: Houghton Mifflin.

Slater, F. M. (1972). Quaternary pollen analysis in secondary school ecology. Journal of Biological Education, 6, 109-117.

Smith, E. L., & Anderson, C. W. (1984). Plants as producers: A case study of elementary science teaching. Journal of Research in Science Teaching, 21(7), 685-698.

Solomon, J. (1980). Teaching children in the laboratory. London: Croom Helm.

Stenhouse, L. (1987). An introduction to curriculum research and development. London: Heinemann.

Stewart, J. C., Hawcroft, D. M., & Bourne, W. F. (1974). Experiments in whole leaf photosynthesis. Journal of Biological Education, 8(4), 207-212.

Stokes, D. W. & Stokes, L. Q. (1985). A guide to enjoying wildflowers. Boston: Little Brown.

Stuart, M. (1982). VNR color dictionary of herbs and herbalism. New York: Van Nostrand Reinhold.

Sykes, G. (1983). Public policy and the problem of teacher quality: The need for screens and magnets. In Shulman, L. S., & Sykes, G. Handbook of Teaching and Policy (p. 97-125). New York: Longman.

Symington, D., & Osborne, R. (1985). Toward professional development in science education for the primary school teacher. European Journal of Science Education, 7(1), 190-228.

Tarleton, R. (1988). Learning and talking: A practical guide to oracy across the curriculum. London: Routledge.

Task Force on Education for Economic Growth. (1983). ACTION for excellence: A comprehensive plan to improve our nation's schools. Denver: Hirschfield Press.

Thomson, J. D. & Neal, P. R. (1989). Wind dispersal of tree seeds & fruits. The American Biology Teacher. 51(8), 482-486.

Tomley, D. (1983). Sun and shade leaves: Some field investigations. Journal of Biological Education, 17(1), 11-12.

Twentieth Century Fund Task Force on Federal Elementary and Secondary Education Policy. (1983). Making the grade. New York: Twentieth Century Fund.

Tyrell, L. (1989). How is this flower pollinated?: A polyclave key to use in teaching. Journal of College Science Teaching, 18(6), 378-383.

Van Den Akker, J. J. (1988). The teacher as learner in curriculum implementation. Journal of Curriculum Studies, 20(1):47-55.

Vibe, F. (1990). Dissecting flowers. Science and Children, 27(8), 15.

Wandersee, J. H. (1986). Plants or animals: Which do junior high school students prefer to study? Journal of Research in Science Teaching, 23(5), 415-426.

Westmoreland, D. (1989). Leaf morphology & light microenvironments: A field exercise. The American Biology Teacher, 51(5), 303-306.

White, R. T. (1988). Learning science. Oxford: Blackwell.

Wigginton, E. (1985). Sometimes a shining moment: The foxfire experience. Garden City, NY: Doubleday.

Wilkinson, D., & Bowers, J. (Eds.). (1977). Gardening: Topic brief #6, LAMP Project. Hatfield: Association for Science Education.

Williams, P. H. (1980). Bee-sticks, an aid in pollinating Cruciferae. HortScience, 15(6), 802-803.

Williams, P. H. (1985). CrGC resources book. Madison, WI: Department of Plant Pathology, University of Wisconsin-Madison.

Williams, P .H. & Hill, C. B. (1986). Rapid cycling populations of Brassica. Science, 232, 1385-1389.

Wilson, C. M., & Oldham, J. H. (1984). Teaching the species concept using hybrid plants and habitats. Journal of Biological Education, 18(1), 45-46.

Wivagg, D. (1987). Do you teach "biology?" The American Biology Teacher, 49(7), 397.

Woods, Peter. (1986). Inside schools: Ethnography in educational research. New York: Routledge & Kegan Paul.

Woolnough, B. & Allsop, T. (1985). Practical work in science. Cambridge: Cambridge University Press.