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A STUDENT-CENTERED BOTANY COURSE FOR HIGH SCHOOL STUDENTS

By

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ABSTRACT

A STUDENT-CENTERED BOTANY COURSE FOR HIGH SCHOOL STUDENTS

By

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A one semester high school botany course was revised with a focus on student involvement. The premise of the unit was three fold: First, this unit was developed to increase student appreciation of plants. Secondly, to teach students that plants are living organisms that respire, consume stored reserves (eat), release substances (excrete), grow, reproduce, respond to stimuli, and adapt. Students were greatly encouraged to develop the laboratory activities and class discussion centered on student ideas. Lastly, this unit was taught to help students apply what they have learned about plants and environment to their own lives.

Alternative assessments were used including journal writing, oral interviews, essay writing, laboratory exercises, group work, and observations. Student retention rose tremendously with this unit versus botany units of the past. Students were able to recall details of the plants with evidence of learning from laboratory experiences. Statistical analysis of pre and post tests displayed an increase in learning. Students reported an increase in content details, classroom cooperation, laboratory techniques, and the love for botany.

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I would like to thank my students for their help and patience during the development of this unit. They were very open to new ideas and were very helpful with their comments and suggestions. I am so very lucky to work with such a wonderful group of students each year.

Dr. Merle Heidemann and Dr. Kenneth Nadler provided me the inspiration and support to develop and teach this unit. Many hours were spent by email, phone, and in person helping me on this project. Thank you both so very much.

Without the support of my classmate, Bill Hodges, I think this thesis would have been more difficult to finish. It was fun to work with you and our little unwritten competition kept us both going. Congratulations to you, Bill, as you are also receiving your Masters Degree this semester.

Finally, I need to thank my family. My fiance, David Peterson was so helpful when the computer would not do as I had hoped. Thank you David for your support and proofreading. And, a special thanks to my puppy, Petey, for warming my feet as I typed.

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INTRODUCTION

Statement of problem and rationale of study:

Many high school students think botany, or studying plants, sounds like a boring class. In addition, several students also think it sounds like a easy class to take or a "blow-off" class that does not require much thinking or work. In fact William Ganong wrote in 1910, "most people undoubtedly consider botany a much easier subject than zoology." Why do students believe this to be true? My purpose begins with changing students' views of botany. I want my students to enjoy botany and to enjoy learning about science through the avenue of botany.

More importantly, students rarely refer to plants as living organisms. Most teenagers don't even notice plants unless it is a household chore to water them or to mow the lawn each week. However, plants are the ultimate source of energy in our lives and are somewhat closer to our daily interests than some other areas of science. Therefore, another purpose of this project is to help students learn that plants are a group of important, diverse, living organisms that respire, consume stored reserves (eat), release substances (excrete), grow, reproduce, respond to stimuli, and adapt. Also, students should understand that plants play an important role in their lives; take the information they learn and apply it to their own plants, lawns, and other botanical experiences.

I have taught at least one section of a course on Botany for four years, which is a semester course option for students to take in the life sciences. I have never enjoyed using a text book as the main driving force in my teaching. However, when faced with a topic in which I had little training, the textbook was an obvious starting point to begin my planning. I also relied heavily on the Michigan Essential Goals and Objectives for Science Education (MEGOSE). (See Appendix A for detailed objectives assigned to life sciences and specific ones included in the botany unit).

In the past three years of teaching botany I usually began with taxonomy and classification. Then I would lead the students up the taxonomic ladder of the plant kingdom, beginning with algae, mosses and ferns and eventually touching on higher plants such as flowering plants. With this organization, students never had time to study the higher plants and their detailed characteristics. On the other hand, I saw the need to keep plant evolution on the forefront. In addition, as we worked through the material, students unfortunately sought out answers from me instead of thinking on their own.

Therefore, I wanted to streamline the discussion of lower plants (algae, mosses, and ferns) to allow more time for investigation into the higher plants (seed plants). I had never really "covered" hormones, artificial propagation, response to stimuli, adaptations, plant nutrition, and life cycles of higher plants in the past. These topics were treated superficially in the past with a small reading assignment or lecture. However, my new unit was designed to allow the students time to question and investigate these topics on their own. I wanted the students to confront their misconceptions about botany and construct new knowledge about higher plants through experimentation and class discussion. In doing this, I redesigned 12 weeks of curriculum and created new laboratory exercises for the botany course.

Review of pedagogical literature:

I have always thought I had an understanding of the latest pedagogy. I have been trained in the conceptual change model, where students construct their own knowledge through dispelling their misconceptions and building new ideas. (Strike and Posner, 1992) In this format of teaching, learning is a process of creating personal meaning from new information and prior knowledge. Students are encouraged to analyze, compare, predict, and hypothesize about the natural world. In a traditional setting knowledge exists outside the student, is teacher centered, creates passive learners, and has a heavy reliance on textbooks. In a conceptually based classroom, knowledge exists within the student where students are cooperative learners that are actively involved in testing their ideas. (Schulte, 1996) However, I had not successfully transferred some of those teaching strategies from my biology course to my botany courses. Therefore, in this new botany unit the students and I developed more hands-on laboratory activities where the students investigate and question.

Most of us remember listening to lectures and memorizing diagrams and flow charts in our biology classes in high school. Unfortunately, we were passive learners in this setting and we never were given the opportunity to really think and question. Too often high school science courses are stuffed with content that overwhelms students and teachers. Rapidly expanding textbooks emphasize memorizing answers rather than exploring questions. The later is what I believe to be true science and I want my students to be engaged in science not just study what others have learned. (Sousa, 1996)

Through my education training I have learned some of the latest terms given to this age old idea of education. Some call it the "Constructivist Approach" while others call it the "Conceptual Change Model." To me they are very similar where the basis for each centers on students doing the questioning and investigating that leads to their constructing their own knowledge. (Strike and Posner, 1992.)

To prepare students for success in the future, schools must emphasize how to critically think, analyze, and apply information rather than just acquire information. (Schulte, 1996) It was once assumed that rote basic skills should be taught and mastered before going on to higher order thinking skills. However, formulating thoughts are commonly requested in today's workplace. In 1989, Science for all Americans was written by The American Association for the Advancement of Science with a goal to change science, mathematics, and technology education across the country. The focus of the document was around scientific inquiry as the basis for learning:

> Teaching related to scientific literacy needs to be consistent with the spirit and character of scientific inquiry and with scientific values. This suggests such approaches as starting with questions about phenomena rather than with answers to be learned; engaging students actively in the use of hypotheses, the collection and use of evidence, and the design of investigations and processes; and placing a premium on students' curiosity and creativity.

In addition to this focus on students, whole school curriculums are mentioned in this text. Schools do not need to be asked to teach more and more content, but rather to focus on what is essential to scientific literacy and to teach it more effectively. This relates to another problem in my botany course: I was feeling the stress of "getting through" the information but students were not actively involved. I found myself in the position of re-working the curriculum for the course from the beginning to the end.

The old way of memorizing information year after year has not set our society ahead. Knowledge is said to be expanding geometrically, with the world's knowledge base quadrupling in this century. (Cornish, 1996) At this pace, no individual can be expected to keep up by memorizing new information. In addition, workplace requirements push us away from fact based curriculum. To prepare our students for the future, we must emphasize application over memorization. Thinking and questioning should be the rule in any curriculum and this was true of my new botany unit.

The basis for our science curriculum in my school district stems from the Michigan Essential Goals and Objectives for K-12 science (MEGOSE). (1991) Three years ago a small subcommittee of K-12 teachers surveyed the teachers in my district on what they taught at each level and their opinions on those topics. Then the subcommittee divided up the MEGOSE objectives for each grade level. K-7 students now learn a little of life, physical and earth science each year. The objectives for grades 8-12 are more specific as you can see here in Table 1.

Table 1: Science Subjects taught at each grade level

Grade Level	Science Subjects in Curriculum
8	Physical Science*
9	Earth Science and Ecology*
10	Life Science*
11	Physical Science and/or Life Science
12	Physical Science and/or Life Science

***denotes what is required for the 11th grade Science Proficiency Test**

The objectives were assigned to each teacher as were the areas they were required to teach. Some in-service time was provided to help teachers learn how to teach any new objectives assigned to them. At my level in 10th grade, the objectives under the title of Cells, Living Things, Evolution, Taxonomy, and Heredity were to be taught. (Appendix A) The Cells and Living Things objectives were covered in a semester biology class that all 10th grade students took in their first semester at the high school.

Then the 10th grade students chose between zoology, botany, human physiology, and genetics for the second semester. In this second semester, the remaining objectives of Taxonomy, Evolution, and Heredity were infused into each course. Therefore, all 10th grade students were taught the information they need for the state requirements before the proficiency test in the 11th grade. In addition, 11th and 12th grade students can opt to take additional courses in these four areas if they wish. Students who take an additional life science semester revisit the objectives again in a different setting and theme.

As previously stated, the focus for this thesis is the botany course. I have taught the botany course four years, and this project took place in the fourth year. In terms of curriculum, I have felt the pressure of covering the state objectives and teaching more specific botany objectives. Since there were no specific botany objectives in MEGOSE or my district, I spent most of my research summer thinking about what is most important for a botany student to learn.

As a thoughtful writer on teaching botany, William F. Ganong (1910) states that structure, morphology, and experimental physiology of higher plants are very important to a botany course. Although this was many years ago, I found his work to be very interesting. He also suggests that a full semester to a year of botany should be offered to all students. I started to look at my previous curriculum in this light. I had a full semester to teach botany but I wasn't giving the students enough time to investigate morphology or experimental physiology in higher plants. In fact, they weren't really learning much about higher plants at all because I spent so much time on the general state objectives and the lower plants. Ganong suggests that this too can work for many teachers.

> There are teachers who do not agree that it is best to begin in a general course in botany with the study of familiar higher plants, but who prefer some other plan, usually the study of the plants by groups, beginning with the lower forms.

Keeping this in mind, I did want the students to have more time to study the higher plants but starting the semester with taxonomy and lower plants still was important to me and the development of the curriculum.

Review of scientific literature:

In my new botany course, the major theme I tried to stress throughout the semester was that plants are living organisms that consume stored reserves (eat), respire, release substances (excrete), grow, reproduce, respond to stimuli, and adapt to their environment. Several of these topics were covered in general biology; however, I wanted my students to discover these characteristics in plants. I focused on the life cycle of flowering plants, hands-on genetic studies, plant nutrition, adaptations, hormones, and tropisms.

The primary source I found most useful in my research of these topics was the Wisconsin Fast Plants (WFP) Manual.™ (1989) Previously, teaching life cycles, plant nutrition, and genetics was done using the textbook and worksheets. I also thought there was too little time for the students to investigate science around these topics. The *Brassica rapa* (WFP)™ is a relative of the mustard plants and has a very short life cycle. Students were able to germinate, grow, cross-pollinate, and observe the entire life cycle in a little over one month. Students were able to see several generations and explore genetic questions in the course of our semester. Figure 1 is a diagram of the life cycle of the *Brassica rapa*.

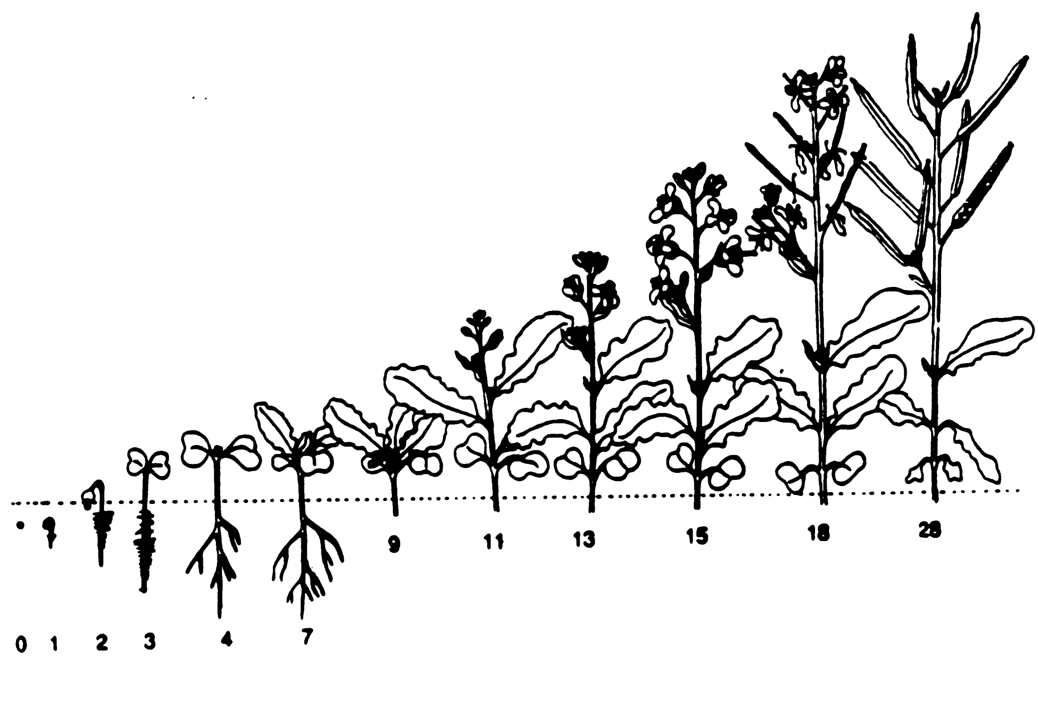

Figure 1: Life Cycle of the *Brassica rapa*

In addition to studying the life cycle of a seed plant, students were able to study basic genetics through growing these plants. The genome of these plants is well known and seeds can be ordered with a specific genotype.

I was unfamiliar with the topic of plant hormones. In plants, the division, growth, maturation, and differentiation of cells is controlled by a diverse group of hormones. Plant hormones are mainly produced in apical meristem, in young leaves, and in growing seeds and developing fruits. Plant hormones control branching patterns, stem elongation rates, and responses to stimuli. (Devlin, 1983)

Some major kinds of hormones include auxins, cytokinins, and gibberellins. Auxin is a well known plant hormone also known as indoleacetic acid (IAA). High concentrations of auxin stimulate elongation of stem cells and inhibit elongation of root cells. Growing roots manufacture hormones called cytokinins. These hormones move upward in plants and some cytokinins stimulate cell division and can cause seeds to sprout. Cytokinins inhibit elongation and cause cells to grow thicker. They also stimulate lateral bud growth.

The last hormone, gibberellin, is most commonly used in the laboratory exercises I created. Gibberellin was first found in Japanese rice plants in the 1920's. It was thought that some long, tall and spindly rice plants had a disease found to be caused by a fungus *Gibberella fujikuroi* that produced the hormone. Later it was discovered that higher plants also produce gibberellins. (Wareing and Phillips, 1981)

A plant's response to a stimulus is another important characteristic to study. This can be mimicked by applying hormones to the plants. Tropism is another term for a plant's response to a stimulus. Phototropism is a plant's response to light while gravitropism is a response to gravity. Students were also interested in chemotropism, a response to chemicals, and thigmotropism, where a plant responds to touch. (Goodin, 1984)

Demographics of the classroom:

I teach in a suburban area of Lansing, Michigan with the high school housing grades 10-12. The population of the high school was approximately 1100 students during the time of this study including 120 students with disabilities. The school population is not ethnically diverse, with approximately 90% of the student body being Caucasian. However, the population is very socio-economically diverse.

The high school has been very progressive in professional development. The school restructured its Wednesday mornings to include a three hour block of time for teachers to work with faculty from a local university, while students would not arrive until 11:20 a.m. for classes. The high school was also a recipient of the Michigan Exemplary Schools Award in both 1989 and 1993. The National Exemplary School Award was given from the U.S. Department of Education in 1993. Change is commonplace and support is often found in both departments and whole staff.

The botany class for this study was taught in the spring of 1997. It was made up of 20 high school students with 9 seniors, 6 juniors and 5 sophomores. The class consisted of 11 males and 9 females during the study. Four students in the class were classified as special education students, mostly all LD (low development). Three quarters of the students planned to go on to a four year college directly after high school.

IMPLEMENTATION OF UNIT

As stated previously, the main area of the botany course that needed changes was the second half when the higher plants were studied. In addition to adding new techniques and laboratory exercises in teaching the higher plants, I needed to streamline the discussion of the lower plants to provide time for in-depth study of the higher plants. In the past I taught most of the semester on environmental issues, lower plants, and the student individual projects. I used to end up with only a couple of weeks to teach life cycles of higher plants, hormones, nutrition, tropisms, and other topics related to higher plants. A basic outline of the new semester is as follows and a "*" denotes topics where new techniques and laboratory exercises were added for this study. These techniques and laboratory exercises will be summarized and informally evaluated in the next section.

Weeks 1-3:	Taxonomy, Survey of Kingdoms Monera and Protista
Week 4:	Start individual project (library research, design and set-up)
Week 5:	Algae*
Week 5-6:	Mosses
Week 7:	Ferns
Week 8:	Introduction of new unit (thesis) with start of seed plants* Seeds and Roots
Week 9-10:	Mitosis and start Wisconsin Fast Plants (WFP)™*
Week 11:	Stems and Leaves
Week 12:	Leaves, Photosynthesis, and Earth Day projects
Week 13:	Meiosis and flowers*

Week 14: Genetics*

Week 15: Plant nutrition*, houseplants, and artificial propagation*

Week 16: Adaptations* and hormones* in higher plants

Week 17: Responses to stimuli in higher plants*

Week 18: Final evolution discussion tying the semester together

Week 19-20: Work on final project presentations and papers

Student presentations of final projects to class

The individual projects mentioned above were assigned to students each year that I taught botany. Basically, students chose a topic they were interested in studying on their own such as the effects of acid rain on plants, grafting as a means of artificial propagation, pesticides affect on plants, or plant hormones. Students researched their topic in the library, designed experiments, recorded data, and presented findings on their projects throughout the semester. The experiments were set-up in the classroom and students would have time (5 minutes) each day to make observations before whole class instruction. Their final assessment included a detailed paper outlining their project and what they had learned. They were also required to discuss at least three specific topics in their individual projects that were part of the whole class curriculum. The final exam grade was 50% a written exam and 50% their individual paper and presentation.

In terms of new teaching techniques, my intent was for the class to be student centered, where student questions directed the investigations. Quite often class would begin with a question from the previous day. I often began class with a journal question or two about where we have been and where the class would like to go next, keeping in mind that I also had a background plan. Rarely did I need to step in and steer the class in a direction I had wanted. On the contrary, students' questions almost always lead down the same path I had planned.

IMPLEMENTATION AND EVALUATION OF LABORATORY EXERCISES

This section summarizes each laboratory exercise or hands-on activity incorporated into this unit. My summer research focused on creating these new interesting and meaningful laboratory exercises for the students. A rationale of each exercise is also included in this section. Often these laboratory exercises were used as a reference for students as they were encouraged to design their own labs on occasion.

Get Help With Kelp! (Medicinal Properties of Algae)

Algae has been used as a medicine for centuries. Mariners once used algae as a medicine where they wrapped wounds in bandages of kelp, or seaweed. Several of my students have asked whether this were true so I worked on a lab exercise for them during my summer research. (Appendix B)

The students placed kelp soaked discs on bacterial cultures of *Bacillus subtilis.* The students also prepared discs of other antibacterial products found in the local drugstore. The students looked for a zone of inhibition around each disc after 2-3 days. This zone is an area where the bacterial growth has diminished and evidence of the product on the disc killing the bacteria. The students gained knowledge of bacterial cultures and sterile techniques. Students also were able to connect this information to a previous unit on the kingdom Monera.

The best level of antibacterial results, or the best "zone of inhibition", occurred with some of the over the counter products but students did observe at least a small zone of inhibition around the kelp disc. Therefore, I would consider this lab a success.

Algae Food Fest!

I decided to enhance the algae unit with some samples of algae from local grocery stores and health food stores. Students also found through research that algae are often used as a thickener and additive in low fat foods. Previous to this activity students thought algae were just some seaweed that they really never encountered. In this activity, we prepared "Algae Milkshakes" and tasted other algae rich foods. We also read articles on the importance of Algae. Students really enjoyed this day of Algae and still referred to it later in the semester.

The students liked tasting different kinds of algae and learning about how it is used. The students were able to apply their knowledge of algae growth, uses, and structure to other plant groups. When later studying asexual and sexual reproduction in seed plants, several students referred back to our discussions on algae. I saw more evidence of enthusiasm and knowledge retention after this activity than in previous years without the Algae food fest.

Seeds Alive

This laboratory exercise was used to help students see that seeds are alive. Tetrazolium is a solution farmers and seed production corporations use to detect seed viability. The students placed the seeds in the tetrazolium solution and after a few hours the embryo inside is dyed pink from the carbon dioxide production as a result of cellular respiration. (Appendix C)

When I introduced this lab to my students it was in the middle of a class discussion on whether or not a seed was alive. I was very pleased with the discussion but the students were at a point where they needed to test their hypotheses. Since they considered something that was alive would give off carbon dioxide, I mentioned I had this test for them to use. I was very pleased that the students were able to use the tetrazolium test as evidence of their ideas on seeds. When I had taught about seeds before, the students were lead to the textbook or diagram to find out what a seed was. The students as well as myself were much more involved in the discovery of seed viability with this laboratory than in the past.

Wisconsin Fast Plants Lab Exercises

I adapted several lab exercises from the Wisconsin Fast Plants Lab Manual™. (See Appendices D-G for detailed protocols). I chose the WFP™ because of their short growing cycle and ease of use by students. I previously was not successful at teaching the life cycle of flowering plants because I lacked a good model. With the WFP™, students could question, investigate, discuss and answer their own questions about the life cycle of seed plants.

1. It's Superplant!

The other exercises that we conducted with WFP™ included the plant nutrition study. (Appendix D) Students studied the effects of under and over fertilizer application on WFP ™. Each lab group planted with varying fertilizer pellets in each container.

Unfortunately, several of the students' plants died and our results varied with some plants with only 1-2 fertilizer pellets doing well and some with 10-15 pellets doing just as well. It was easier when I had students just add a variable amounts of plant food to house plants. Students could always see signs of under nourishment, such as yellowing, curled, or dying leaves, with plants not fed. Students also saw these signs with overfeeding house plants.

2. Congratulations! You are a parent!

We also conducted genetic studies on the WFP™. (Appendix E) Students acted as bees with cotton swabs and cross-pollinated the WFP™. They grew F_1 heterozygous wild-type plants and crossed them. Students also observed the growth of the F_2 rosette and wild-type flowers and their role in reproduction.

The offspring were some tall and some short plants which lead to a discussion on dominant and recessive traits. This was very successful and interesting to the students. For the first time, I felt like the students were actually excited about plant genetics. Obviously, reading about Gregor Mendel had not been enough in the past.

3. We're Going to Pump you up!

This was a hormone lab that was the students' favorite. I adapted this lab from the gibberellic acid (GA) experiment in the Wisconsin Fast Plants manual, (Appendix F). Students took the short plants (rosette) from their genetic crossing of the second generation of plants, F_2. They added GA to the leaves every other day for a week and recorded the results.

The short plants that were not given GA stayed the same height while those that were given GA grew several centimeters over the others. Obviously, students were able to see that GA is a growth hormone in plants. This was another one of the laboratory experiences students referred to several times throughout the semester. In terms of teacher preparation and cost, this lab exercise was very easy and the results were wonderful.

4. Flower Dissection

Students studied the anatomy of the WFP™ flowers. We also dissected flowers from a local flower shop. Each group dissected a rose, daisy, carnation, iris, lily, dandelion, and some other various flowers and identified and sketched the parts in each flower. (Appendix G)

Flower structure and function were also studied with the WFP™. In the past students would only dissect flowers from the local florist. We again investigated flowers this way this year. However, the students had more basic knowledge of flowers before the dissection this time because of their work with the WFP™. Their ability to identify flower parts and discuss their functions was greatly enhanced after acting as "bees" in cross pollination of their Fast Plants.

Plantenstein! It's Alive

In the past, students read about artificial propagation in their textbook and we drew upon their prior knowledge of vegetative propagation in class discussions. I often had a cutting in the classroom for them to observe but the students had no opportunity to reproduce plants vegetatively (asexually). Therefore, I adapted a laboratory exercise from Grow Labs book to help students study artificial propagation. (Appendix H)

A student asked about a cutting I had on my desk and several others offered their ideas as to how plants can reproduce asexually. This conversation lead them to engage in this exercise, "Plantenstein." I brought in several different vegetables and plants for the students to use and students brought in cuttings from their homes as well. Questions arose as to how to conduct vegetative propagation successfully, which lead us to the video laser disc player and their textbooks as resources. The students were researching their questions, not mine.

After some discussion on various techniques, such as layering, cuttings, and grafting, the students tried some of these techniques. I gave them this written procedure as a guideline after they had basically designed this lab themselves. This was a long term project since it takes weeks for some plants to begin developing roots.

Students were impressed and amazed by each others' work. They were quick to check on the progress of their plantenstein everyday which increased enthusiasm for botany. I even had two students say they had some cuttings of spider plants at home from their parent's plants. This activity also sparked two students to research more on grafting and its possibilities as their individual projects.

During this laboratory experience, students were driving the discussion and the investigations which was what I had planned. For the first time teaching vegetative propagation, students were excited to transfer their knowledge to their home gardens.

<u>Starch munching enzymes in seeds!</u>

Hormones were one of the topics I had trouble fitting into my old curricular structure. I developed two experiments to help students study these in two contexts, one of which was discussed in the Wisconsin Fast Plant lab section above. This second lab allowed students to see the effects of hormones and enzymes on seed germination. Normally, in germinated barely seeds the hormone gibberellic acid stimulates the production of the enzyme a-amylase in the aleurone layer of the endosperms. This enzyme then digests the starch in the seed for the embryo.

In this experiments, students place cut barely seeds with embryos removed on starch agar with gibberellic acid (GA). The GA supplements the induction of a-amylase by the embryo. Students developed the agar plates with iodine and "halos" appear where the starch has been digested. (Appendix I)

The students were able to observe the halos in the starch agar showing where the enzyme had digested some of the starch in the agar in place of digesting the starch in the seed. The students really enjoyed this lab and understood the concepts well. Before incorporating this lab, students rarely imagined hormones playing a role in seeds. This lab prompted more discussions on hormones throughout the plant and their functions.

Plant Adaptations.

I chose plants from local stores that had thick leaves (jade, aloe), aromatic plants (geranium), and other plants displaying adaptations. After obtaining about 10 different plants I placed them around the lab with some basic questions about adaptations. The students moved through the lab stations answering the questions I had prepared for them. I also had them list more questions that arose during their small group discussions at each table. See Appendix J for a detailed description.

Setting up plant adaptations lab stations shifted the focus of learning from me and back to the students. We began the class with a discussion about plant adaptations. At

one point the students had exhausted their own ideas and needed some situations to fuel more discussion and questioning. I presented this lab at that point and when we later went back to the plant adaptation discussion, the students were able to draw upon the examples they had seen rather than simply asking me for the answers. Their small group discussions in the lab created more questions to study further. This lab exercise also connected well with a field trip to the MSU gardens and greenhouses. Students connected plants and information from this activity to what they had seen on the trip.

A-MAZE-ing Light Experiments:

And Other Tro-I-pic Experiments:

Both of these experimental protocols were written during my summer research (See Appendices K and L). However, most students designed their own experiments using these protocols as references. The idea of plants responding to stimuli of light, water, and gravity came up in class one day. After some discussion the students broke up into groups and each group took one stimuli and related tropism to study. The phototropism group designed a set-up where a plant had a light on one side of it only and they observed it grow toward the light. The geotropism group turned plants on their side and upside down. The hydrotropism group decided to limit the water given to the plant and only water the plant in one place each day.

This was a long term experiment (1-2 weeks) since it takes days for a plant to show its response to light. Each group was able to see the plant grow toward the light, in fact the group with the maze had their plant twist through the maze twice. The geotropism groups were able to see the changes in the plants growth toward the north.

The hydrotropism group had a bit more trouble because their plants died since they were trying to limit the water to one place but they did see the root growth increased in the direction toward the water.

I also brought in a Mimosa plant for the students to investigate. They were each able to "play" with the leaves. When you brush your finger across one of its leaves or stems it fold up its leaves and appears to wilt, or thigmotropism. I was pleased to see students connect this response to turgor pressure and osmosis during these trials.

EVALUATION OF EFFECTIVENESS OF UNIT

I used several different methods of evaluation for this unit. Students participated in this evaluation by their own choice. Students and parents were informed about my thesis unit and that evaluation would be part of the unit but not part of their grade. They received grades for labs and tests. However, the pre-tests, post-tests, surveys and interviews were not part of their class grade and were used to gather information about the effectiveness of this unit. All of the students and parents agreed to be part of the study as they filled out and returned a permission slip. (Appendix M)

I evaluated this unit on two levels. One was the measuring students' improvement with a pre-, and post-test. Another was comparing interviews with students of a past class with the class in this study. In addition to these two formal evaluations, I also had informal conversations with students and read and analyzed the journals they kept as a record of their learning throughout the semester.

The data obtained from the pre-, and post-test instruments provided information on whether students had learned basic content. I looked for their ability to name characteristics of life and how each are displayed in plants. I wanted the students to use their lab experiences as evidence of these characteristics. I asked this question in a variety of ways to see how well they really understood the information and to provide different styles for students to respond. Appendix N shows the instrument I used for both the pre and post test.

I designed a rubric to assess their responses to the pre and post test, using a 0-3 point scale, where 0 was low and 3 was high. I finalized the rubric after reading all of the assessments. (Appendix O). Scores for each student are shown in Table 2. The mean, median and mode for both the pre and post test are shown in Tables 3 and 4.

Table 2: Table of Pre-test and Post-test Scores

Student	Pre-test Score	Post-test Score
1	8 (44%)	17 (94%)
2	7 (39%)	12 (67%)
3	5 (28%)	14 (78%)
4	4 (22%)	11 (61%)
5	10 (56%)	13 (72%)
6	8 (44%)	15 (83%)
7	7 (39%)	13 (72%)
8	3 (17%)	7 (39%)
9	8 (44%)	14 (78%)
10	3 (17%)	6 (33%)
11	8 (44%)	15 (83%)
12	4 (22%)	13 (72%)
13	2 (11%)	16 (89%)
14	10 (56%)	16 (89%)
15	9 (50%)	13 (72%)
16	8 (44%)	11 (61%)
17	8 (44%)	13 (72%)
18	4 (22%)	11 (61%)
19	5 (28%)	13 (72%)
20	2 (11%)	12 (67%)
	Avg: 39%	Avg: 72%

Table 3: Introductory Statistical Analysis of Pre-Test Data

High Score	**10**	**(56%)**
Low Score	**2**	**(11%)**
Mean Score	**6.15**	**(34%)**
Median Score	**7**	**(39%)**
Mode Score	**8**	**(44%)**

Table 4: Introductory Statistical Analysis of Post-Test Data

High Score	**17**	**(94%)**
Low Score	**6**	**(33%)**
Mean Score	**12.75**	**(71%)**
Median Score	**13**	**(72%)**
Mode Score	**13**	**(72%)**

The null hypothesis in this situation would suggest that any differences in the scores between pre and post tests would be due to chance. The alternative hypothesis is that any increase in post test scores would be due to real learning on the part of the students.

To determine whether or not there is a real difference between the scores, I first found the gain between the pre and post test scores for each student. Then I averaged the gains to find the sample mean, or x bar. This value was 6.5 and the standard deviation of the sample was 2.7. The null hypothesis would predict that the population mean (of the gain) will be close to zero. The alternative hypothesis states that the population mean (of the gain) will have a positive difference, significantly greater than zero.

I used the t test to compare the means between the pre and post tests. The resulting t was 10.77. At the 0.05 significance level on the t table and a 19 df resulted in a critical value of 1.729. Therefore, I rejected the null hypothesis since my t was greater than 1.729. I can statistically conclude that the treatment given to the students did in fact impact their learning and was not due to chance.

I also interviewed a group of students from the botany course I taught the year prior to this group in the study. I also interviewed a group of students from this study group the following fall after they had the botany course. Therefore, the same amount of time had passed for each group between finishing the botany course and the interview.

I was looking for both opinions about the botany class in general and retention of content material. I was pleasantly surprised to see that students in both groups overwhelmingly enjoyed botany. Several students gave examples of which labs they liked. However, the study group was much more detailed in their description and was more specific about what they had learned. For example, where one student in the "old" class described the flower dissection as "interesting and fun" a student in the study class was able to describe names of the parts of the flowers and drew upon his knowledge of the WFP™ in his explanation:

> "Yea, I really liked the flower dissection even though it sounded kinda gay I think the fast plants got me into it at first since we saw the little buds and anthers and petals. But the bigger flower dissection was cool because we could really see the parts. I didn't know roses had lots of ovaries or that the ovary was down in the stem part in the purple flower.....the iris."

Students in the old class all said they enjoyed the individual projects the best. These were projects the students chose to study. I had incorporated these projects in the old curriculum and kept them in the new curriculum since they worked so well. The individual projects ran the entire semester and the students were in charge of documenting all changes, writing a detailed report and presenting what they had found. I did notice that the students in the study course were much more detailed in reporting their results and were able to connect their individual projects to other content in the course much better than students in the past.

However, the study group of students also listed other labs as their favorites. The "Seeds Alive" lab and the WFP™ labs were also well-received. When I asked them why, they often responded that those labs helped them "learn more and actually see stuff happening." The tetrazolium test in the "Seeds Alive" lab served as a common thread in our classroom discussions. Students drew upon the seeds creating carbon dioxide through cellular respiration as evidence as a characteristic of life.

It was my perception that our class discussions increased with this new curriculum.

Instead of me up in front lecturing on botany, students generated ideas together and questioned one another. I was still looked to for the final "answer". However, much of the learning and decision making had occurred by that point.

DISCUSSION AND CONCLUSIONS

Overall, the entire semester was a clear improvement compared to the past few years of teaching botany. My time up front lecturing decreased as students were more involved in thinking about and planning the course. From the interviews, my students were also more interested in botany since they were more actively involved. I was also much happier teaching this new curriculum and approach.

I worked hard to involve my students in designing more experiments rather than handing out a "cookbook" lab for them to mindlessly work through. The Wisconsin Fast Plants (WFP)™ provided several opportunities for students to design their own experiments with the WFP™. Several students mentioned the WFP™ during interviews as a means to practice the pollinating techniques they learned and to actually see the genetic traits appear. They were able to tie information covered in lecture or class discussion to the plants. For the first time, my students were able to conceptualize the role of each part of the flower since they were actively involved in monitoring the life cycle of the plants. Since the students were acting as pollinators they had to learn the appropriate flower parts and they followed their development.

One of my goals for the unit was to help students conceptualize that plants are living organisms that consume stored reserves (eat), respire, grow, release substances (excrete), reproduce, respond to stimuli and adapt. In the past my students were able to describe these at a superficial level without much laboratory evidence to support their claims. However, this group of students that were taught this new unit drew upon laboratory experiments for an understanding of each characteristic of life. I was very impressed with their retention of details. The anatomy of the flower was much more emphasized in the study group compared to the old group. I was also impressed with their level of detail in describing processes in plants such as cellular respiration with results from the tetrazolium lab as evidence. For the first time in years I saw students really understand this complex process since I saw less confusion on their faces and they used to forget all about cellular respiration when asked about energy in cells. With this study group, students were able to explain how plant cells use energy not just how they make glucose through photosynthesis. I am definitely going to use this laboratory and discussion in my other biology classes.

The genetics objectives that are required to be taught by the state were better understood by students with this unit. Genetic problems used to be so abstract with students constructing Punnet squares and trying to visualize the offspring. With growing one generation (F_1) of plants, crossing them, harvesting the seeds, and planting the next generation, students were able to follow the emergence of genetic traits. Once the students grew the F_2 generation they immediately saw traits emerge in the expected ratio. This was much more effective than doing Punnet squares on paper. This would be another unit I would like to transfer to my biology class. However, since it involves plants and so much time it might not work well. I will continue to look into other ways to teach our genetic objectives in that class.

One area I feel needs some work is the plant hormone unit. Actually, time was the big roadblock. Unfortunately, this topic was left to the end of the course and we simply ran out of time. We did conduct the gibberellic acid lab on the WFP ™ but I don't think the students really understand that hormones are a regular part of life and not just something you "take" to build you up. There was a lab I tried during my research using the hormone IAA that was not too successful but I would like to try again. The hormone unit was not as complete as I would have liked. The halo half seed lab that displayed the use of hormones was helpful and I will continue to use it.

Even though the individual projects were not new in this unit, the level of enthusiasm was higher than in the past since the students had more ownership in all areas of the course. They would come to class early and check on their experiments. The level of class discussion not centered on me rose tremendously, compared to past years, since the students designed their own experiments to test their misconceptions. Of course, I directed them and gave them ideas at times, but the background design was often done as a class before I would hand them a lab or activity. Students became astute listeners of each other for the first time. I had been able to do this in my biology classes but since I lacked background knowledge and laboratory ideas in botany, I was not successful in transferring this kind of teaching to my Botany class in the past. Now students challenged each other and constantly said, "let's test your idea in lab!"

Comparisons of pre and post test data indicates the knowledge gained by students during this course. In the pre test students had to leave some questions blank due to lack of knowledge or they reverted to the 5th grade level answers. With the post test I had students requiring the entire hour to answer the five essay questions. Student took extra paper and elaborated each question with details from lab. A few students chose not to go into so much detail but with probing and interviewing I could see their growth as well. The content retention the following fall after this new unit was much more detailed and specific than the past fall interview of students taught the old way.

This unit was more than just a unit. I redesigned about 12 weeks of material of the semester and finally incorporated my true teaching style into the teaching of botany. I feel the botany students are now able to describe how a plant is a living organism and they have increased their appreciation for plants. The course used to be known as a boring class about plants. Now, the rumors mention the words "fun, challenging, and student directed". This unit is still a work in progress and I look forward to the continuing challenge.

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APPENDICES

APPENDIX A

APPENDIX A

MICHIGAN ESSENTIAL GOALS AND OBJECTIVES FOR HIGH SCHOOL IN THE LIFE SCIENCES

Cells:

1. Classify cells/organisms on the basis of organelle and/or cell types.
2. Explain how multi-cellular organisms grow, based on how cells grow and reproduce.
3. Compare and contrast ways in which selected cells are specialized to carry out particular life functions.
4. Compare and contrast the chemical composition of selected cell types.
5. Compare the transformation of matter and energy during photosynthesis and respiration.
6. Explain how essential materials move into cells and how waste and other materials get out.
7. Explain how cells use food to grow.

Living Things:

1. Classify major groups of organisms on the basis of the five-kingdom system.
2. Describe the life cycle of an organism associated with a human disease.
3. Explain the process of food storage and food use in organisms.
4. Explain how living things maintain a stable internal environment.
5. Describe technology used in the prevention, diagnosis, and treatment of diseases.

Heredity:

1. Explain how characteristics of living things are passed on from generation to generation.
2. Describe how genetic material is passed from parent to young during sexual and asexual reproduction.
3. Explain how new traits may be established in individuals/populations through changes in genetic material (DNA).

Evolution:

1. Describe what biologists consider to be evidence for human evolutionary relationships to selected animal groups.
2. Explain how a new species or variety may originate through the evolutionary process of natural selection.
3. Explain how new traits might arise and become established in a population.

APPENDIX A

Ecosystems:

1. Describe common ecological relationships among species.
2. Explain how energy flows through familiar ecosystems.
3. Describe general factors regulating population size in ecosystems.
4. Describe responses of an ecosystem to events that cause it to change.
5. Describe how water, carbon dioxide, and soil nutrients cycle through selected ecosystems.
6. Explain the effects of agriculture and other human activities on selected ecosystems.

Constructing Knowledge:

1. Develop questions or problems for investigation that can be answered empirically.
2. Suggest empirical tests of hypotheses.
3. Design and conduct scientific investigations.
4. Gather and synthesize information from books and other sources of information.
5. Discuss topics in groups by being able to restate or summarize what others have said, ask for clarification or elaboration, and take alternative perspectives.
6. Reconstruct previously learned knowledge.

Reflecting on Knowledge:

1. Justify plans or explanations on a theoretical or empirical basis.
2. Describe some general limitations of scientific knowledge.
3. Explain how common themes of science, mathematics, and technology apply in selected real-world contexts.
4. Discuss the historical development of key scientific concepts and principles.
5. Evaluate alternative long-range plans for resource use and byproduct disposal in terms of environmental and economic impact.

APPENDIX B

APPENDIX B

GET HELP WITH *KELP*!!

Algae has been used as a medicine for centuries. Mariners wrapped wounds in bandages made of kelp, or seaweed. These mariner and other folk remedies have received renewed interest in recent years. Scientists are studying the antimicrobial qualities of many species of algae.

Kelp and seaweeds are brown algae. Brown algae are multicellular and can grow quite large. Some look like aquatic plants with root systems and blades that resemble leaves. The cells of brown algae contain chlorophyll, responsible for photosynthesis, but their golden-brown pigment usually masks all other colors, including green.

Materials:

10 g powdered kelp
distilled water
parafilm
plates of *Bacillus subtilis* on nutrient agar (6)
filter paper (use a hole punch to make discs, rinse in rubbing alcohol)
forceps
ruler
Bunsen burner

Procedure:

1. Label three plates "kelp" and three plates "control".

2. Mix a few drops of distilled water with the powdered kelp until it is slightly soupy.

3. Place 12 filter paper discs in the kelp soup. Soak for 10 minutes.

4. Soak 12 filter paper discs in distilled water.

5. Place 4 discs on the appropriately labeled petri dish. Place one disc in each quadrant of the plate. Seal each plate with parafilm and store in a cupboard for two days. *Use sterile techniques during transfer. Heat forceps in burner to kill bacteria left on it.

6. After two days, measure the "zone of inhibition" around each filter paper disc. This is the area where the bacteria are no longer present. Measure this distance in mm.

APPENDIX B

<u>Results:</u>

Plate	**Zone of Inhibition (in mm)**
Kelp 1	
Kelp 2	
Kelp 3	
Control 1	
Control 2	
Control 3	

<u>Conclusion:</u>

Write a conclusion for this experiment:

How could we extend our study here? What other experiments would you like to try along these lines of testing medicinal purposes?

Source: Dashefsky, Steven. "Using algae for medicinal purposes", <u>Botany: High- School Science Fair Experiments</u>. TAB Books. New York. 1995. Pps. 116-120.

APPENDIX C

APPENDIX C

SEEDS ALIVE!!

Throughout the semester we have been investigating lower plants which do not produce true seeds for reproduction. Today we will start with seed plants which are in the sub-phylum Spermopsida. Some questions we have had include: what are seeds made up of? Are seeds alive? Let's answer some of those questions today.

There is a test that professionals who test seeds for viability use called the Tetrazolium test. This test will stain pink the area of a seed that is undergoing respiration. We will conduct this experiment in lab.

Procedures:

1. Seeds were soaked in a warm water solution overnight to soften them. The tetrazolium solution has also been pre-mixed. (0.1% solution which is 1 part of the 1% solution with 9 parts water. The 1% solution is 1 gram of tetrazolium powder in 100 ml distilled water)

2. Place the seeds in 30 ml of the tetrazolium solution overnight. Record the results below. If you need results within the hour, slice the seeds longitudinally.

Predictions:

From the information given in the introduction, what do you predict will happen?

Results:

Draw a picture and describe the results of the seeds soaked in the tetrazolium solution overnight:

Questions and Conclusions:

1. What part of the seed do you think was dyed pink? Why?

2. How do you think professionals like farmers might need to use the tetrazolium test?

Adapted from Botany 301 Lab Manual. Kenneth Nadler. 1970

APPENDIX D

APPENDIX D

SUPERPLANT! ......Or not?

Introduction:

Previously we have discussed the necessary materials for a plant to live a healthy life. They include light, water, CO_2, and minerals. There are three main minerals that are required for normal growth that are obtained through the air or water. They include carbon, hydrogen, and oxygen. However, nitrogen, phosphorus, and potassium are also essential and are obtained in the form of ions in solution which are absorbed by plant roots.

These nutrients are usually filtered through the system of soil, air, and water for most outdoor plants but when it comes to house plants or gardens, humans seem to think their magical plants come in a bottle. Often we will add these in the form of "Miracle Grow" or some other commercial product. The dosage for most plants is once a week at most, with several types of plants only needing a feeding once every month or two. So, it makes since that the manufacturer would know, right? Well, let's find out if more plant food could produce a superplant!

Materials:

18 RCBr seeds (Wild type fast plants)
31 fertilizer pellets
Six film containers with holes in the bottom
6 felt wicks
soil, water, light
ruler

Procedures:

1. Label each plant with the number of fertilizer pellets you will add to each (0,1,2,4,8,16).

2. Place the wick in each container with 1/2 of it inside and the other 1/2 outside. Fill each container 3/4 full of moist soil.

3. Place the appropriate number of fertilizer pellets in each container as marked.

4 Lightly cover the fertilizer pellets with soil to bring soil level right near the top. (Add soil to container 0 too.)

5. Add three seeds into each container. Lightly cover the seeds with soil.

APPENDIX D

6. Water your containers from the top with a dropper and water. Repeat this for 3 days. Place the seeds on the self-watering container under the grow lights.

7. When the plants come up, thin to one plant per cell.

Predictions:
Which level of fertilizer do you predict will provide the best nutrient level for the plant. Why?

Results:
Record your results in the data table below:
-measure height from cotyledonary node (where the cotyledons are attached) to tip of plant.
-record the number of true leaves, don't count the cotyledons here.
-general appearance should include plant color, size of stems, leaves, etc.

0 Fertilizer Pellets:

Date	Height (mm)	# of leaves	General Appearance:

1 Fertilizer Pellet:

Date	Height (mm)	# of leaves	General Appearance:

APPENDIX D

2 Fertilizer Pellets:

Date	Height (mm)	# of leaves	General Appearance:

4 Fertilizer Pellets:

Date	Height (mm)	# of leaves	General Appearance:

8 Fertilizer Pellets:

Date	Height (mm)	# of leaves	General Appearance:

APPENDIX D

16 Fertilizer Pellets:

Date	Height (mm)	# of leaves	General Appearance:

Questions and Conclusions:

1. Which nutrient concentration level produced the healthiest plant? Describe the growth and appearance of that plant.

2. How would you tell whether or not a plant was experiencing stress from too high a fertilizer concentration? Can you distinguish nutrient-excess symptoms from nutrient-deficiency symptoms? How?

3. a. Does the day at which the cotyledons begin to turn yellow differ for each nutrient level?

   b. At which nutrient level do the cotyledons turn yellow earliest? Explain.

4. Why do you think too much fertilizer causes these symptoms exhibited here? Explain.

APPENDIX D

5. **Some compounds are more soluble in water than others, and soil pH is important in determining nutrient solubility. Devise an experiment which explores the relationship between soil pH and nutrient availability.**

Experiment adapted from "Plant Nutrition" from the Wisconsin Fast Plants Growing Manual. 1989

APPENDIX E

APPENDIX E

Congratulations! You are a parent!

Ok, not really....but I got your attention! At any rate, we are going to experiment with sexual reproduction IN PLANTS! Gregor Mendel, known as the father of genetics, conducted similar experiments on pea plants in his garden in 1865. We will be "crossing" wild type tall plants (F_1) predicting the genotypic and phenotypic ratio, planting their seeds and harvesting the next generation. (F_2)

To complete this exercise, we will need to recall some definitions. Restate the definition of each term below. Use your notes or your book if you need some help.

Genotype:
Phenotype:
P_1 generation:
F_1 generation:
F_2 generation:
Punnet Square:
homozygous:
heterozygous:

Procedures:

1. You will be given the seeds from F_1 generation of a mating of two parent plants. The parents were both homozygous for their trait, one being tall and one being short. (Tall is dominant) using a punnet square, predict the genotypic and phenotypic ratios of their offspring below:

2. You are going to mate the F_1 generations to produce the F_2 offspring. When the flowers are open and the pollen is exposed, you will act as the bee and cross pollinate them. To do this, obtain a Q-tip and lightly brush along the flower□s anther of one plant. Carry that pollen to the stigma of another flower by lightly brushing across it. Take some pollen off of the plant you just brushed and take it back to the original plant.

3. Continue this process, with flowers in pairs, until all have been pollinated. Place the plants back on the water system, under the lights.

4. Repeat this process for the next 2-3 days. On the last day of pollination, remove any unopened buds and mark the date on the pot label. Water and document growth, changes, and any other notes on the progress of your plants in your journal weekly.

APPENDIX E

5. Allow the seeds to mature. Seed pods begin to elongate within 3-5 days and seeds mature in 20 days.

6. If your plants now (F_1) were the offspring in #1, predict the offspring when crossing them here. (You are predicting the F_2 generation here. Use a punnet square and give the genotypic and phenotypic ratios)

7. 20 days after the last pollination, the seeds should be ready to harvest. Remove them from the watering system and allow them to dry for 5 days. Harvest the seeds by gently rolling dry seed pods between your hands over a collecting pan. Plant the seeds following the planting instructions given. Continue documenting growth, changes, etc in your journal weekly.

Questions and Conclusions:

1. What were the results of your F_2 plants? How many were tall? How many were short?

2. What is the class average of tall : short plants in the F_2 generation? Does this match your prediction done above in #6 of the procedures?

3. Are your tall plants homozygous or heterozygous? (F_2) How could you find out?

4. Draw the life cycle of the plant, rapid-cycling brassicas, below. Label the following parts or stages of development: diploid, haploid, asexual, sexual, gametophyte, sporophyte, fertilization.

5. What kinds of problems or special concerns came up during this experiment? What did you learn during this experiment?

Source: "Mendelian Genetics", Wisconsin Fast Plant Growing Manual. University of Wisconsin, Madison. Carolina Biological Supply Company Publishers. 1989.

APPENDIX F

APPENDIX F

We're going to *PUMP* you up!

Normal plant growth depends upon several different factors. We have already learned that plants need water, sunlight, CO_2, and nutrients to become healthy. However, there are also internal factors that regulate growth and development in plants, called hormones. Hormones are organic substances produced in one tissue and transported to another tissue, where their presence results in a physiological response. Some examples of hormones include; auxins and gibberellins. Auxins are hormones that promote root development in low concentrations, however, they can inhibit the growth of lateral stems in higher concentrations. In this experiment we will investigate the role of gibberellins on the growth of a homozygous rosette plant, which is short with its leaves flat against the soil.

Materials:

6 rosette plants (8 days old)
ruler, tape
Distilled water
2 droppers
Gibberellic Acid solution (.01g/ 100ml water)

Procedures:

1. Label 3 plants "GA" for Gibberellic Acid. Label 3 plants "control".

2. Drop one small drop of GA on each leaf of the three plants labeled "GA". Drop one small drop of water on each leaf of the control plants. Repeat this every other day from day 8 to day 16 of the growth. Remember these plants are on day 8 today. Keep your solutions refrigerated.

3. Measure the growth in cm of each plant on days you add the water or GA.

Results:

Date	**Age of Plants**	**Height of GA plants**	**Height of Control**

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Questions and Conclusions:

1. How do your plants results compare with the class results? If there are differences, how could you account for them?

2. What is the effect of GA on plant growth in the rosette plant?

3. Make a comparison of the water-treated plants and the GA-treated plants. Do your results prove that the rosette is a gibberellic acid-deficient mutant? Explain.

4. How would you describe the role of Gibberellic Acid in plants?

5. Read the information in your text and in the handout provided to you on Gibberellic Acid. Describe in detail the specific role this hormone has on plants.

6. If you were to cross (mate) one plant that got GA with one that did not, what would you expect the offspring to look like? Why?

7. What environmental factors can affect stem elongation?

8. Would varying the location of the application affect the plant growth response? Design an experiment to test your hypothesis.

This experiment was adapted from "The Effects of Gibberellic Acid on Wild-type and Rosette Plants," Wisconsin Fast Plant Growing Manual. 1989

APPENDIX G

APPENDIX G

FLOWER DISSECTION!

Today we are going to dissect several flowers to identify their reproductive and non-reproductive parts. List the flowers your group has been assigned below. Draw pictures of the external anatomy and the internal anatomy of each flower. Using your textbook, label all parts clearly on each flower.

Flower 1:

Flower 2:

Flower 3:

Flower 4:

Flower 5:

Flower 6:

APPENDIX H

APPENDIX H

PLANTENSTEIN! IT'S ALIVE!

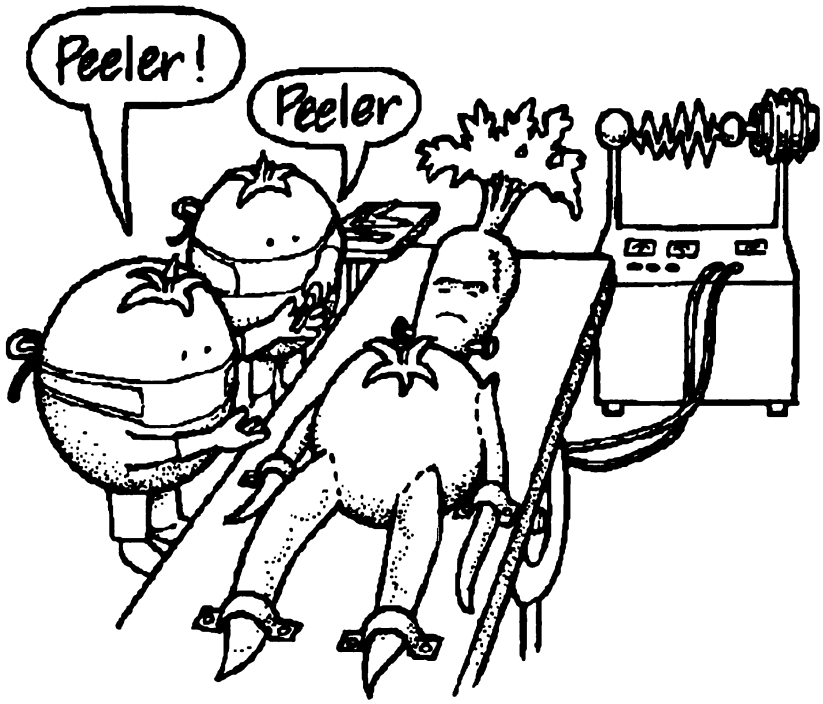

FIGURE 2: Plantenstein

Plants and some simple animals such as sponges have an adaptation for survival that humans lack - the ability to regenerate an entire new organism from a piece of the original one. Although starfish can restore their missing legs, and even humans can regenerate skin cells to heal a wound, neither we nor most other animals can produce an entirely new organism from parts. Many plants, however, are capable of vegetative propagation or asexual reproduction, producing a new, complete individual from part of another one.

Unlike reproduction from seed, only one parent is involved in vegetative propagation. Rather than containing genetic material from two parents, the offspring produced asexually are the same genetically as the parent plant, that is they are clones.

APPENDIX H

In nature, vegetative reproduction is quite common in plants. Over millions of year, plants have developed adaptations to be able to reproduce in different ways. Most plants that naturally reproduce vegetatively will also reproduce from seeds. Some of the structures plants use to reproduce vegetatively include tubers (potatoes), bulbs (garlic), runners (strawberries), rhizomes (iris), and crowns (asparagus). Because every cell in a plant contains all of the genetic information for that plant, many plants can also be propagated from parts such as leaves, roots, and stems.

FIGURE 3: Plantenstein Propagation

Human take advantage of these plants' reproductive abilities not only by planting the structures illustrated, but also by using artificial propagation techniques. For instance, we propagate house plants by taking cuttings from leaves, stems, or roots. With the proper warmth and moisture, plant growth hormones stimulate the production of roots, and sometimes leaves, at the cut surface. Another method, one of the most sophisticated vegetative propagation techniques used by human, is "tissue culture," in which a new plant is produced from just a few cells of the parent under carefully controlled conditions.

Today, we will try to propagate a variety of different plants. We will plant some directly in soil and others in warm water to wait for roots to form. You may want to ask at home if there are any plants you could take a small cutting from to try to propagate!

Materials:

1 large tub or container per group
4-6 small cups or beakers
Potting soil, water
plant cuttings, vegetables, leaves, etc. (Healthy cut with leaves)

Procedures:

1. Fill a long, narrow tub with soil. Using your cuttings from several plants in the classroom, seeds, onions, beets, and potatoes plant them in your tub in the form of

APPENDIX H

a face. Be sure to take an identical cut of each and place each individual cutting in a cup of water.

2. Sketch below your face and label which plants you used in each place of your face:

3. Water your "Plantenstein" and place it in the window. Place your cuttings that are in water in the window too.

4. After a few weeks, gently tug on each "re-planted" portion. Observe any changes that occurs in the water propagated samples too. Include your results in your answers to the questions below.

Questions and Conclusion:

1. Generally describe the growth of each type of cutting, both in soil and in water.

2. How do face parts grown from seeds differ from those grown from plant parts?

3. How is one small piece of a leaf or a root "know" how to grow the whole plant?

4. Describe at least 3 advantages to vegetative propagation.

5. Describe at least 3 disadvantages to vegetative propagation.

6. What other types of plants or plant parts would your like to propagate? Why?

Experiment adapted from "Plantenstein", GROW LABS: Activities for Growing Minds. National Gardening Association. Vermont. Pg. 141 1990

APPENDIX I

APPENDIX I

STARCH MUNCHING ENZYMES IN SEEDS!

We have been studying seeds, their anatomy and how they germinate. When seeds germinate, the embryo digests the starchy endosperm by producing the enzyme α-amylase, secreted by another layer of endosperm, the aleurone cells. The sugars from this digested starch is the useable food for the embryo. In germinated wheat, the hormone gibberellic acid stimulates the production of this enzyme by the aleurone layer.

Normally, the wheat embryo produces Gibberellic Acid (GA) after being soaked in water. The GA is then transported to the aleurone layer which produces the amylase enzyme to break down the starch. In this experiment, we will remove the embryo and try to induce this response with adding GA to an agar for the seeds. We will also add starch to the agar to see if the enzyme will digest this starch.

Materials:

25 hulled wheat seeds (soak in distilled water overnight)
1% Clorox solution
1 mg Gibberellic Acid
Petri dishes
parafilm
Iodine reagent
Sterile forceps, paper towels, water
Sterile 500 ml Erlenmeyer flask

Procedures:

Part One: Preparing the agar/starch/GA solutions:
(Done for you)

1. Bring 1000ml of distilled water to a near boil. Add 30g of agar and stir to dissolve. Add 2g of soluble starch and stir until the mixture is transparent.
2. Carefully weigh 1 mg (.001 g) of gibberellic acid into 100 ml of methanol (0.01mg/ml, final concentration)
3. Remove 1.0 ml of the above solution and add this to 100 ml of methanol. Label this solution #4.
4. Remove .2ml of solution #4 and add to 1.8 ml of methanol. Label this solution #3.

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5. Remove .2ml of solution #3 and add to 1.8 ml of methanol Label this solution #2
6. Remove .2ml of solution #2 and add to 1.8 ml of methanol. Label this solution #1.
7. Divide the starch agar into 200 ml amounts using the flasks.
8. Add 1.0 ml of each of the GA standards to each flask. The remaining agar will be the control.
9. Pour each solution into labeled sterile petri dishes and store in the refrigerator until needed.

Part Two: Preparing the seeds and setting up the plates:

1. Cut the embryo off of each seed using a razor blade. Use the results of the Tetrazolium lab to guide your cuts.(pink portion is the embryo) Discard the embryo.
2. Sterilize the half-seeds in 1% Clorox solution for 20 minutes.
3. Rinse them several times in distilled water and blot dry on sterile paper towel.
4. Place 5 half-seeds, cut end down, on each agar plate uniformly.
5. Apply parafilm on each plate and incubate in the cupboard for two days.
6. After 48 hours, develop the plates with iodine reagent. Measure the halo around each seed. Record below.

Results:

Record the diameters of the halos here:

Conclusion:

1. Write a statement concluding what you learned from this experiment.

2. How could we further the study of hormones and enzymes?

Sources: Nadler, Kenneth. Botany 301 Lab Manual. Michigan State University. 1970.
Hach, Cheryl. Michigan State University, Division of Science Education Masters Thesis Research. 1996.

APPENDIX J

APPENDIX J

PLANT ADAPTATIONS

Teacher Instructions:

Set up six lab stations students can rotate through to observe several different plant adaptations. Basically, students should be able to recognize that leaves have different adaptations that enable them to survive in specific environments.

a. One potted plant with a plastic bag over it. Water well before hand. One plastic plant with a bag over it. You may also want to try a cactus with a bag over it too. Students should see water droplets on the first plant's bag.

Thought questions:
What does this setup help us infer about leaves? (Students should recognize that an important function of leaves is to transpire or release water. Review how water is important for photosynthesis, however, excess water is given off or transpired through the stomata in the leaves.)

b. Jade plant leaf, Lettuce plant leaf. Which one can hold the most water? Why?

Thought questions:
Place two sponges at the same station. (same size)Wet both and place one in a plastic zip-lock baggie. How does this artificial example display what is happening in the leaves.
(Share with the students that many leaves found in dry environments are thick and fleshy. Thicker leaves, like the thick sponges, an hold more water than thin leaves can. Many dry-environment plants also have a waxy coating. The waxy coating (simulated by the plastic bag on the sponge) on many dry-climate leaves prevents water from escaping.)

c. Large stem plant (cactus) and a thin stemmed plant (ivy)

Thought questions:
How does having a thick stem and spines instead of leaves help the cactus survive?

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(The cactus stems serve as storage tanks for water. They also carry out photosynthesis normally carried out by the leaves of other green plants. Spines do not photosynthesize or have stomata, and thus water loss from the plant is reduced. Since the stem's surface area is relatively small compared to its volume, the stem transpires relatively little water.

d. Place a geranium, mint, or other aromatic plant with lettuce, radish or other unscented plant.

Thought questions:
How do you think the leaf's aroma might be an adaptation for survival? What examples can you think of in nature? Have you ever used unscented bug repellent?
(Share that many plants produce scents that repel predators or attract pollinators.)

e. Hairy leaf (bean, tomato, lamb's ear) and a smooth leaf.

Thought questions:
Do you think a bald head or a hair covered head would dry out faster? How do people cope with extremes in climate such as cold and wind? How do you think leaf hairs might feel to an insect looking for a meal?

f. Epiphytes (plants that grow without soil, in the air)
One plant in soil

Thought questions:
What role does soil play for the potted plant?
How does the plant without soil get what it needs?

(Epiphytes have adapted to live high in trees in the rainforest. They have adapted to take in necessary nutrients from the air.)

APPENDIX K

APPENDIX K

A-*MAZE*-ing Light Experiments!

Have you ever noticed a plant growing toward the light? We know that plants need light to undergo photosynthesis. The light reaction of Photosynthesis is where the plant uses the direct light energy to break water to release oxygen and hydrogen for later reactions. A plant's response to light in its environment is called PHOTOTROPISM. In this investigation, you will design a maze to observe how a plant will respond to meet their basic need for light.

Procedure:

Using a shoe box and scraps of cardboard, you will create a maze with one hole for light at one end of the maze. You will then place a plant at the opposite end of the maze inside the box and observe the growth of the plant over two weeks. We will also place the same kind of plant out of a maze and measure its growth as a control. After you have designed your maze, sketch your maze on paper and predict which path the plant may take.

Predictions:

Sketch of maze and predictions of growth:

Predictions of growth of control plant:

Results:

Date/plant in maze or out?	**Measurements**	**Additional Results**

Date/plant in maze or out?	**Measurements**	**Additional Results**

Questions and Conclusions:

1. Generally describe the growth of plant in the maze and the plant without the maze over the two weeks. Why do you think these results occurred?

2. How do you think the plant in the maze box would have grown if there had NOT been a hole in the box? Why?

3. In your own words, what do you think is going on inside of the plant for these results to occur?

4. What part of the plant seems to be responding to the light the most? Read the attached information PHOTOTROPISM and explain why this special growth is occurring.

Source: Grow Labs: Activities for Growing Minds. National Gardening Association. Vermont. 1990.

APPENDIX L

APPENDIX L

Other *TRO-I-PIC* Experiments!

Now that we have experimented with a plant's response to light, let's see if other things can induce a special response. Have you ever wondered why roots grow down and stems grow up? Is this always true? Do plants grow this way in space, without gravity? Do plants grow in response to the amount or placement of water? LET'S FIND OUT!

PART 1: Geotropism

Procedures:

1. Germinate some radish or corn seeds in moist paper towel overnight. Place one seed in each dish with the seed pointing to a different position in each dish. Point a seed at 12:00, 3:00, 6:00, and 9:00. Place some wet paper towel behind the seeds to lightly press them against the petri dish. Tape the lid on to the dish and place in a cupboard to eliminate any light from the experiment. Check your seeds daily and document below in data table one below. (Figure 1)

2. Prepare another petri dish with one seed in the middle of the dish.

3. Place the petri dish on its end with 12:00 straight up in some clay on a table. Each day when we check our seeds, document any changes and rotate the dish one quarter of the way with tomorrow putting 3:00 on top, the next day 6:00 on top, and so on. Document any growth or changes in data table 2 below.

Predictions:

What do you predict what will have happened after one week in each petri dish?

12:00 dish:

3:00 dish:

6:00 dish:

9:00 dish:

Rotated dish:

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Results:

DATA TABLE 1: Seeds at positions on a clock.

Date / Dish Type	**Results**
Date: 1. 2. 3. 4.	
Date: 1. 2. 3. 4.	
Date: 1. 2. 3. 4.	
Date: 1. 2. 3. 4.	
Date: 1. 2. 3. 4.	

APPENDIX L

DATA TABLE TWO: Rotated Seed

Date	**Results**

<u>Questions and conclusions:</u>

1. Generally describe the growth of the seeds over the course of the experiment.

2. The title of this experiment is 'geotropism'. In your own words, describe what you think this term means.

3. Read the section in your text about geotropism. Describe the specifics that are occurring in the plant for this reaction to occur.

4. How do you think raising food in space might be different from growing crops on Earth? What concerns may arise?

APPENDIX L

Part 2: Hydrotropism

Procedures:

1. Tape three seeds in a row on a strip of cardboard. Place the strip of cardboard in the center of a coated paper plate. Tape one rolled up wet paper towel on one end and one dry paper towel on the other end. Place the set-up in a ziploc baggie and observe the results over the next week. Keep the baggie in a cupboard throughout the experiment to eliminate light from the experiment.

Predictions:

What do you think will happen to the seed growth over the next week? Why?

Results:

Date	**Results**

Questions and Conclusions:

1. Generally describe the growth of the seeds over time. Why do you think these results occurred?

2. How do you think the plant 'knew' where to grow? What parts of the root play a role in this experiment?

3. What other kinds of experiments could we design to observe more tropic responses?

Source: Grow Lab: Activities for Growing Minds. National Gardening Association. Vermont. 1990.

APPENDIX M

APPENDIX M

** This is a sample of the permission slip sent to students and parents of the study group. This same permission slip was used October 1996, April 1997, and October 1997.

Date: October 5, 1996

To: Students and Parents of Botany

Dear Students and Parents,

As discussed previously in class, we will be studying how plants are living organisms. We will be experimenting on plants to show that they eat, excrete, grow, reproduce, respond to stimuli, and adapt. In past years of Botany we have not done some of these experiments and studies. I am interested in studying whether this approach helps you better understand this concept. I am presently working to complete my Master's thesis at Michigan State University and I would like to use data collected from your pre and post assessments, samples from your journals, and data from interviews. Your name will not be used in my thesis, that is fine. There is no penalty in denying permission to use your data and you will not be at any personal or academic risk. If you have any questions or concerns feel free to call me at the high school at 694-2162.

Sincerely,

Ms. Heather Neiswonger

________I give Ms. Neiswonger my permission to use data collected from my pre and post assessments, my journal entries, and interviews. I understand that Ms. Neiswonger will maintain my confidentiality with all of my student data.

_______I do not wish for Ms. Neiswonger to use my data as part of her Master's thesis. I understand there is not penalty for choosing to do so.

_____________________________ _______________
Student signature Date

_____________________________ _______________
Parent/Guardian signature Date

APPENDIX N

APPENDIX N

Botany Thesis: **Pre-Test/Post-Test**

1. Are plants alive? How do you know?

2. What are the characteristics of a living thing? (Name at least 4)

3. Describe how a plant displays these characteristics of life. Be specific.

4. Draw the parts of the plant that are involved with EACH of the characteristics you described above. Link each characteristic to the appropriate part.

5. Describe laboratory experiences you have had that have helped you discover plants are living organisms. Be specific and include experiences connected to each characteristic of life.

6. Create a concept map with these terms: (Use the back of this paper)
   **Interconnect as many as possible

hormones	genes	traits
stimuli	light	growth
leaves	reproduction	

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APPENDIX O

PRE AND POST TEST RUBRIC FOR SCORING

I used a scale of 0-3 (0 being low)

1. **Are plants alive? How do you know?**

0- No answer, just a "yes", negative information, nothing correct for reasons
1- "yes" and 1-2 characteristics that are poorly explained
2- "yes" and 2-3 characteristics that are somewhat explained. Or just list the characteristics of life.
3- "yes" 3, 4 or more characteristics of life fully explained in detail.

2. **What are the characteristics of a living thing? (Name at least 4)**

0- No answer
1- 1-2 characteristics of life (eat, breathe, grow, reproduce, respond to stimuli, excrete, adapt.)
2- 3-4 characteristics of life
3- More than 4 characteristics of life

3. **Describe how a plant displays these characteristics of life. Be specific.**

0- No answer, may only explain one briefly or incorrectly
1- Explains 1-2 with vague explanations
2- Cites specific labs and evidence on 2-3 characteristics. May describe 4 but they are very vague
3- Explains 4 and more characteristics in detail by citing labs and evidence

4. **Draw the parts of the plant that are involved with EACH of the characteristics you described above. Link each characteristic to the appropriate part.**

0- Nothing or a plain plant with nothing labeled.
1- Draws a part of a plant with 1 characteristic labeled. Or draws a detailed plant with 1-2 characteristics labeled.
2- Draws whole plant or at least 3 main parts (roots, stems, leaves, flowers) Explains 2-4 characteristics with this diagram.
3- Draws whole plant and labels 4 or more parts linked to the characteristics.

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5. **Describe laboratory experiences you have had that have helped you discover plants are living organisms. Be specific and include experiences connected to each characteristic of life.**

0- Nothing
1- Describes 1 lab and links it to 1 characteristic
2- Describes 2-3 labs and links them. May have vague or incorrect descriptions.
3- Describes 4 or more labs and links them in detail to the characteristics.

6. **Create a concept map with these terms: (Use the back of this paper)**
****Interconnect as many as possible**

hormones	**genes**	**traits**
stimuli	**light**	**growth**
leaves	**reproduction**	

0- Nothing or 1-4 terms linked but no connecting terms or arrows. No detailed descriptions off of the terms.
1- Has most terms linked but not with explanations. May have a few explanations.
2- Has all terms linked, some arrows but lacks detailed explanations and descriptions. Lacks multiple connections.
3- Links genes to traits and explains. Links genes to controlling reproduction.
Light is absorbed by leaves and used for photosynthesis to make glucose.
Stimuli can be a hormone, light, or other tropisms.
Stimuli can lead to growth.
This concept map is in good form with all terms connected with arrows and connecting terms above the arrows. There are other bubbles to make further connections.

APPENDIX P

APPENDIX P

Master's Thesis: Fall Interviews-Pre Thesis students (*Also used with Post Thesis students)

1. Describe a little about my project to the student. (no names used, be honest, etc)

2. What do you remember about Botany?
   -what first comes to mind?

3. What words would best describe how you feel about Botany?

4. What words would best describe what and how you learned in Botany?

5. What did you most enjoy? Why?

6. What did you most dislike? Why?

7. What does it mean to be alive?

8. Is a plant alive? How do you know?

9. Describe how a plant displays characteristics of life.

10. What labs helped you learn this?

(10 b. Do plants excrete? proof? Do plants reproduce? proof? Do plants eat? proof?)

11. Concept map with key terms.....words on cards....