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USING THE PURPLE LOOSESTRIFE PROBLEM AS A CASE STUDY APPROACH TO TEACHING BOTANY

By

Lisa Marie Weise

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ABSTRACT

USING THE PURPLE LOOSESTRIFE PROBLEM AS A CASE STUDY APPROACH TO TEACHING BOTANY

By

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A case study approach to botany was developed to increase student motivation and student experimental design. Case studies provide a framework for students to return to through out a course. This case study used a current environmental problem, the spread of the exotic species, purple loosestrife, in our local wetlands to grab student's attention. Students asked questions that led them to study the course objectives when researching the answers. Purple loosestrife is an ideal plant for the classroom as it is readily available in our local wetlands and grows quickly from root balls. Students were able to study the plants by growing the small root balls collected from a local pond in the fall.

Student learning was assessed in by comparing written answers pre tests to written answers to journal questions and post tests. The study focused on seven students with a range abilities that represented the class of twenty one students. Students had interest in the purple loosestrife problem and asked thoughtful questions that led them to possible solutions. By designing experiments and solving problems students gained a new lasting, understanding of plants.

To Matt and Ellie, who fill my life with love, happiness and giggles.

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INTRODUCTION

During the second semester of sophomore biology at Holt High School, students choose between four courses: Botany, Physiology, Human Genetics, and Zoology. Since the 1995 school year, fewer than 5% of all sophomores choose to take Botany. Botany is the only spring semester class that does not use a case study approach. Compared to the fall general biology course, Botany was a class where students spent less time designing experiments in the lab and more time following instructions. Although the course had several student experiments and an individual project, students learned many concepts and vocabulary, with little or no connection to their world. For example, in the past students memorized the different plant tissues and their functions by examining fixed slides and diagrams. In the revised course, students learn tissues when that knowledge helps them understand objectives about water movement, food transport, photosynthesis, and cell specialization (see appendix A).

Nationwide, botany is a neglected topic in biology classes for several reasons: most biology teachers have more preparation in zoology and interest in animals, students prefer animals to plants, and general high school biology textbooks provide less information on plants than animals (Hershey, 1996). Students around the world failed to select plants as an interesting topic in a study (Honey, 1987). According to David Hershey, high school botany does not make plants relevant to students. Plants are perceived as boring by students, and often presented in boring ways by teachers. Labs using plants often include students using prepared slides and scripted experiments

(Hershey, 1992). The essential role plants play in our lives encourages few students to take an interest in learning about Botany.

In order to integrate a real world problem I introduced the exotic species, purple loosestrife to my spring botany class in a case study format. After describing how purple loosestrife has been spreading in our local wetlands and taking over habitat normally occupied by native species, students wanted to know more. To my delight, their hands went up with questions and interest about how this plant is affecting our local environment. They wanted to participate in finding and working towards a solution. Their questions and interest led me to investigate using purple loosestrife as a case study for Botany. The plant purple loosestrife acts as an anchor to the real world when used as a central problem. A local problem, like purple loosestrife, makes connections between school and the world outside of school. Students can easily identify the plant, have concerns about how it affects our area, and ask thoughtful questions. These questions provide a framework for our class, and allow students to return to a familiar problem through out the semester.

The case study approach attempts to engage students in science by having them solve problems. Instead of thinking of science as a body of knowledge that should be given to students, the case study approach encourages learning science as a problem solving process. This gives students ownership over the direction of the course in addition to the organization of a central problem. Using a case study to map out a course allows constructivist teaching and student discovery.

According to the constructivist teaching model, described by Brooks in The Case for Constructivist Classrooms, student prior knowledge and experience shapes the way they learn. Students are more likely to take interest in problems that have relevance to them. In order to learn new concepts, students must find a way to fit new ideas into the way they make sense of the world (Brooks, 1993). Constructivist teachers use prior knowledge and student ideas to shape their curriculum. Unfortunately, students' previous ideas about the world are littered with misconceptions that can block the understanding of new scientific concepts (Driver et. al., 1995). Plants are no exception, by looking at what goes into and out of purple loosestrife, this unit tackles some of the common misconceptions about plants:

1. Plants are static (Hershey, 1992).
2. Plants get food from the soil (Driver et. al., 1995).
3. Plants take water in from the leaves.
4. Not all plants are alive (Driver et, al., 1995).
5. Plants do photosynthesis instead of respiration (Amir et. al., 1994).

My students shared these misconceptions. In order to address these naïve ideas, the new unit uses student discovery and student experimental design as they attempt to figure out how purple loosestrife has become a dominant species in Michigan wetlands. For, example when students answer the question, "How does the environment affect the growth of purple loosestrife?" students designed experiments. In groups they studied how different amounts of water affect the growth of purple loosestrife, how different soil types affect the growth of purple loosestrife, and how heat and light affect the growth of purple loosestrife. To understand what was happening to the plants in their experiments, students needed to find out more about how water moves through a plant. In order to understand how the environment interacts with purple loosestrife students study how plants survive.

Purple loosestrife grows near our High School and thrives through out the wetland areas in Michigan. Students easily find areas with Purple loosestrife when given pictures of the plant. They often ask, "Is that the purple plant that grows on the highway? Is that the plant that grows at Grand River Park?" The dominant plants with purple flowers take over river banks, roadsides, and ponds in our area.

Purple loosestrife, *Lythrum salicaria,* is considered a nuisance species by the U.S. Fish and Wildlife Service (United States, n.d.). For the past 50 years purple loosestrife, originally from eastern Europe, has aggressively taken over wetlands along the eastern corridor and is spreading westward. Michigan and the rest of the Midwest began to see purple loosestrife in the early 1900's. Recently, national attention focused on Purple loosestrife because of its ability to displace cattails and alter the habitat of wetlands. Purple loosestrife is a perennial that establishes a substantial root mass each year. Each plant has several stalks that sprout from the root mass and are topped by purple flowers capable of generating around 3 million seeds per plant (Malecki, 1993). This remarkable number of seeds makes purple loosestrife a fierce competitor with other plants after any ecological disturbance. Roadsides and man made ponds are often covered with purple in July! This makes herbicide control measures futile, as purple loosestrife seeds blanket the wetlands in much higher numbers than any other wetland plant. In fact, purple loosestrife takes over after a disturbance or herbicide attempt. Once established in a community purple loosestrife grows quickly and spreads using runners and seeds. This ability to grow and live through harsh conditions makes purple loosestrife an ideal classroom plant.

In addition to connecting botany to the real world, the new unit with a case study approach has a focus on student experimental design. Generally, case study approaches focus more on science process and students learn science content along the way. In an article about using case studies in biology, Freeman states, "The goal in most of our case-method teaching is not so much to teach the content of science (although that does clearly happen) but to teach how the process of science works and to develop higher-order skills of learning." (Freeman, 1994). In the past, the lab work in botany generally practiced following directions and using lab equipment. This does not mirror the process of science as real problems rarely have one simple correct answer that is achieved in an hour of lab work. According to Roth, in his book (Roth, 1995) about authentic science, open inquiry is an essential part of any science class. He notes that when students are allowed to formulate their own problems and generate unique solutions, they not only engage in real problem solving, they take ownership for their work and their motivation is increased.

The purple loosestrife case study allows students to generate questions and problems around purple loosestrife to work on in the lab. While solving these problems, students think about how to test possible solutions. They design unique experiments with their own ideas by collaborating in small groups. Each group of students presents their experimental design, results and conclusions to the class. The presentation of results and analysis of other student experiments mirrors real science as students explain the rationale behind their methods. The use of inquiry in the classroom engages students and allows them to discover new concepts instead of being told these concepts (Uno, 1990).

In order to address purple loosestrife as and environmental problem students ask questions about how purple loosestrife survives. While examining how purple loosestrife interacts with the environment students learn about plants in general. The central question students focused on when looking at how purple loosestrife survives was, "What goes into and out of purple loosestrife?" Upon completion of the unit, students should be able to explain how the entire plant functions together. They should be able to explain how materials move through the plant, and explain why plants need water, oxygen, light, and carbon dioxide to survive on the macroscopic and the microscopic levels. Students should make connections between the plant tissues they see in the microscope and the movement of water from the soil, into the roots, through the stem and out of the leaf. Then students should connect the movement of materials in and out of plants to photosynthesis and respiration. They should be able to explain special adaptations that allow purple loosestrife to thrive in wetlands.

Holt High School is a suburban school with approximately 1200 students. All students at Holt High School take a general biology class in the fall of their sophomore year. These classes have full inclusion with ability levels ranging from severely learning disabled students to gifted students. 4.1% of students qualify for free lunch, and 1.9% qualify for reduced lunch, indicating a lower household income. The general biology class, taken by students first semester, uses a case study approach that emphasizes group work, experimental design and the conceptual change model. The philosophy of the science department is to work for a deep, lasting understanding of biological concepts and how they connect to student experiences. We use vocabulary only when needed for communication of a new concept. Students thrive in this environment where they are allowed to act as scientists and critical thinkers (Richmond, et. al., 1998).

IMPLEMENTATION

This portion of the study explains what happened in the classroom during the study in chronological order. In the past, the Botany course studied plants by following evolutionary relationships. Each class of approximately 24 students would start the semester studying algae, work through mosses and ferns, then vascular plants, then the end of the semester was a brief unit on trees. Students rarely saw the connections between units and interest in the algae and non-vascular plants was low. This study attempts to organize Botany around purple loosestrife to provide a more student driven course with more student input and interest in the direction of the course. At the beginning of the semester students investigated purple loosestrife as an exotic species from Europe that has no natural predators in the United States. They began to ask questions that we organized into one big question about how purple loosestrife interacts with its environment, "What moves into and out of purple loosestrife?"

While the question, "What moves into and out of purple loosestrife?" seems rather simple for high school, it offers an opportunity to learn about many parts and functions of plants in depth. This big question was broken into two sections: one focused on water and one focused on carbon dioxide, oxygen, and glucose. It is expected that students will walk away from the unit with a beginning understanding of how plants interact with the world. Also, students should learn objectives that construct new knowledge, reflect upon prior knowledge, and use new concepts from Michigan Essential Goals and Objectives for Science Education (see appendix A). Basically the study is broken into two sections, one about water movement and use in plants and the other about photosynthesis and respiration in plants.

Purple Loosestrife Case Study: The following outline lists the activities and details the objectives for each activity. The activities and labs are in italics. For a complete look at the activities, labs and assessments, please see the appropriate appendix. Specific objectives are in parenthesis through out the outline. Objectives are referred to by number and type. For example "C-1" refers to constructing objective one. Please see Appendix A for a complete list of objectives.

I. Assess Prior Knowledge and identify misconceptions about plants. Students answer questions, in groups, and present their answers to the class (see appendix C-1).

II. Introduce purple loosestrife problem.

  A. Use slides, potted examples of the plant, also handouts from internet on NOXIOUS WEED, and laminated plants (C-4).

  B. Brainstorm: What questions would we need to know the answers to in order to solve the problem of purple loosestrife? (C-1)

  C. Bring in purple loosestrife plant from Grand River. Cut up the root ball and give a section to each group of students. They will pot these root sections and study them through out the semester. (C-2, C-4)

II. Students study the effects of different conditions on the young loosestrife plants.How do materials get into and out of purple loosestrife?

  A. Assess prior knowledge by having students draw large plants and diagram what goes into and out of plants and where. Each group of student will explain how the materials enter and leave the plant and why they need to enter and leave the plant and what happens while the materials are inside the plant.

B. Investigate plants and water. Roots and Stems and Leaves are involved.

   1. *Water tricks demos* (see appendix B-2). Students discover properties of water by looking at 6 different stations (U-5, U-2, U-1).
   2. *Water loss in plants lab* (see appendix B-1). Weigh a geranium with a bag over the pot and soil, so that the only water that exits goes out of the leaves, over the course of several days (U-1, U-3).
   3. *Transpiration rates in plants lab* (see appendix B-3). Students design experiments to see what factors affect the rate of transpiration. Most designs used week old bean plants in graduated cylinders to answer one of two problems: What environmental factors affect the transpiration rate? What parts of the plant affect the transpiration rate? (C-1, C-2, C-3, U-1, U-2, R-1)
   4. *Roots, Stems and Leaves: Structures involved in water transport lab* (see appendix B-5). Look at parts of the plant involved in water transport in the roots, stems and leaves. Students identify tissue in prepared slides and student made purple loosestrife slides. (Microscope lab) U-7, U-6.
   5. Water article (Welch et. al., 1968) and book questions (see appendix B-2). (C-4, R-3)
   6. Students present purple loosestrife labs (R-1).
   7. Assessment includes a lab portion that has students design model plants out of string, felt, sponges and straws. These model plants are designed to take up as much water as possible as high as they can over a 24 hour period (C-3).

III. *What else moves into and out of purple loosestrife?* Look at stomata and leaves & Photosynthesis.

   A. Photosynthesis models and limiting factors activity and Journal writing.

   B. What affects the rate of photosynthesis? (U-7, U-9, U-10).

      1. *Spinach/Purple loosestrife disks lab* (Steucek, 1985):

         a. First time through students followed directions to practice the procedure.

         b. Second time through each group tested different variables using the same basic set up and presented results to the class.

      2. Photosynthesis and limiting factors reading.

   C. *Photoperiod lab* with purple loosestrife (see appendix B10): Students designed labs that tested if the number of hours of sunlight affect the growth of purple loosestrife (C-1, C-2, C-3, R-1).

   D. Students brainstormed questions unanswered by unit about photosynthesis.

   E. Class discussion about photosynthesis questions (U-9, U-10).

IV. What happens to the sugar made in photosynthesis?

   A. Prior knowledge journal on respiration in plants (R-2, R-3).

   B. *Lab: Do different parts of the plant respire?* (see appendix B-10): Students design various set ups to see if different parts of the plant or seedings are giving off carbon dioxide using bromothymol blue.

   C. *Respiration (roots) in plants Demonstration*: Put the roots of a small plant into a pipette that has blue BTB in side. The BTB will turn yellow with in a day.

The water is also transpired during the demonstration leaving air bubbles in the pipette (U-9, U-11, U-12, C-3).

D. *Lab: Respiration rates in seedlings* (see appendix A-8)(U-9, U-11, U-12, C-3, R-1)

V. How can we identify **purple loosestrife**? What other plants does the growth of purple loosestrife affect? How can we identify those plants and study changes in populations of plants over time?

A. Students design and construct plant field guides that are useful locally. This will include (C-2, C-3, C-4, R-1):

1. An introductory dichotomous key.
2. Tree identification including a leaf collection section.
3. A section on plants found in wetlands.

D. Go to purple loosestrife site and assess populations of plants.

1. Students assess 5 quadrats at a local pond infested with purple loosestrife.
2. Back in the classroom we make a class map of what is growing around the pond according to all class quadrats.

E. Students visit purple loosestrife greenhouses on campus for a presentation about the purple loosestrife project at Michigan State University.

Throughout the study students were assessed using different strategies. Students were assessed using journal questions that they answered, class discussions, questions on lab reports, two written tests and a written final exam. Dialog during small group work was also used to measure student progress during the study. The first day of the unit students answered a series of prior knowledge questions that sampled general plant knowledge (see appendix C-1). Students presented answers in groups to the class about what moves into and out of plants. Generally, students mentioned carbon dioxide, water and nutrients going in and oxygen going out. One student noted during the pre-assessment that so many things go into a plant and very few things go out! Although some students had ideas about exotic species, none of the students had heard of purple loosestrife.

The purple loosestrife case study specifically addresses the following common student misconceptions (see appendix C-1):

Misconception:	Number with misconception:	Related Objective (see appendix C):	Related activity (see appendix A):
Plants are static (Hershey, 1992).	19	Using-cells-1,	-Lab: Does purple loosestrife respond to its environment? -Water Tricks.
Plants get food from the soil (Driver et. al., 1995).	21	Using-1, 9, 10, 11, 12	-Photosynthesis Models Activity. -Photosynthesis Disks lab -Van Helmont Reading.
Plants take water in from the leaves.	15	Using-1, 3, 5	Transpiration Rates Lab. Water loss in plants.
Not all plants are alive (Driver et, al., 1995).	7	Using-1, 8, 9	-Respiration in seedlings. -Respiration in plants. -Lab: Does purple loosestrife respond to its environment?
Plants do photosynthesis instead of respiration (Amir et. al., 1994).	20	Using-9, 10, 11, 12	-Respiration in plants lab.

The purple loosestrife problem was introduced using dried purple loosestrife plants and an article about purple loosestrife. Students studied the dried sample in groups and wrote out the characteristics of purple loosestrife. They discussed how purple loosestrife had become and environmental problem in our area by competing with native species for valuable habitat in wetlands. Student quickly pointed out that if native plant species were being replaced by purple loosestrife the other native species in our local ecosystems are affected as well. Next, students generated questions during a class discussion about purple loosestrife after being asked, "What would we need to know about purple loosestrife in order to solve this problem?" Students had immediate interest and concern about purple loosestrife. Several students came to me in the days following to tell me they saw purple loosestrife in several areas around our school! They had several questions about purple loosestrife:

How does it affect other species?

Can it be killed by chemicals?

Why doesn't it reproduce so quickly in Europe?

Does anything eat purple loosestrife?

Are there good things we could use this plant for?

What is purple loosestrife's life cycle?

How often does it release seeds?

What climate does purple loosestrife prefer?

Can we stop purple loosestrife from making seeds?

Where does it grow best?

What previous control measures have not worked?

Does purple loosestrife get any diseases?

Is there any thing in Europe that kills it?

Why is purple loosestrife a problem now, instead of in the 1800's?

Can our local species adapt to having purple loosestrife over time?

How does the environment affect the growth of purple loosestrife?

The students selected "How does the environment affect the growth of purple loosestrife" as their first problem to solve because it included a few of their other questions. Groups of students designed experiments to see how the environment affects purple loosestrife. All students designed labs using the same general format with two plants in different conditions (see appendix B-10). They used the basic steps of establishing a problem, gathering information, forming a hypothesis, testing the hypothesis, recording results and concluding about what the results mean. They worked with this format throughout their sophomore year (see appendix B-10).

All groups planted at least two root cuttings of purple loosestrife so one plant could be used as a control (see appendix B-9). Student experimental designs tested different amounts of water, the porosity of the soil, different temperatures, different amounts of nutrients, and different salinity levels in the soil. After about three weeks of data collection students found that high salinity prevented the growth of purple loosestrife, more water increases purple loosestrife growth, and levels of nutrients seemed to have no effect on the growth of purple loosestrife. Two of the experimental setups did not grow because of lack of watering by the students. Students learned that all of their labs needed more plants and more attention to data collecting and watering to be more successful. Students agreed that findings on twelve plants in our room would not always transfer as general conclusions about purple loosestrife.

Because each *purple loosestrife experiment* connected to water in some way, we began to investigate the movement of water in plants (see appendix B-9). While the *purple loosestrife experiments* were running students had the idea that plants absorbed water from the soil, but also thought that plants absorbed water from the air into the leaves. Most students had difficulty explaining why plants need water at the beginning of the unit, writing, "Plants need water to live". They were not able to explain how water gets to the different parts of the plant from the roots or what happens to water inside the plant. We set up experiments to see what affects the rate that water moves through plants. Experiments about water movement in bean plants addressed two possible problems:

How does the environment affect water movement?

How do plant structures affect water movement?

Each group put week old bean plants in graduated cylinders and tested different variables. Control set ups were compared to experimental set ups that had different variables in each group (see appendix B-3). The following day all students had some water movement and a decrease in the amount of water in the graduated cylinders that was different between their control and experimental groups. Results were presented and students added an analysis of class results to their conclusions. The class concluded that water movement in plants was increased by heat, wind, and light. They also found that water movement was decreased by covering or cutting off some leaves, constricting the stem or cutting off some roots.

While the bean plant labs were running we followed a class experiment. Students covered a potted geranium with a plastic bag so that the only water to leave the plant would exit through the leaves (see appendix B-1). A student then weighed the plant daily and put the mass of the plant on the board each day. Over a period of one week the plant lost half of it's mass! Students were impressed because this far exceeded their predictions of water loss. The results also contradicted the idea that water goes in the leaves, because the mass did not increase.

In order to investigate the how water moves through plants students looked at six different *water tricks* stations (see appendix B-2). Each station demonstrated combinations of capillary action, osmosis, cohesion, adhesion, and surface tension. Student's prior knowledge about special properties of water allowed them to explain some of the stations. Other stations brought up new ideas that they had some trouble explaining. While students had ideas about the polarity of water and surface tension, they had trouble putting these two ideas together. Additionally, they had trouble taking the new concepts about water and applying them to water movement in plants.

Next students investigated the internal structure of plants to understand how the water gets from the soil to the air. In an observational lab students used microscopes to examine prepared slides of roots stems and leaves. Students compared these prepared slides to slides that they made from our purple loosestrife plants in class. It was difficult to compare purple loosestrife stem and root cross sections to the prepared slides because of crude preparation techniques (see appendix B-5). From this lab students concluded that there are a series of small tubes in the roots, stems and leaves. Students were able to state that water is pulled up the plant by the movement of water out of the stomata.

Students read and discussed an article about early experiments in water movement in plants (Welch et. al., 1968). They used this article and the book to answer questions about how water moves through plants. The readings helped students pull the concepts from the various labs together to see how the structure of the plant is geared towards water movement.

As a class we made a chart that organized the labs and demonstrations that were related to properties of water, and how water moves through the plant:

Demonstration or Lab(see appendix A-1):	Property of Water:	Relevance to Plants:
Toothpick star	Osmosis	Water moves into the roots.
Paper clip, screen on the jar, and drops on a penny.	Surface tension, cohesion, polarity	Creates the pull in the cohesion-tension theory
Different size tubes	Capillary action, adhesion	Movement of water up the stem.
Bag around the leaf, loss of mass in the potted plant with the bag.	Evaporation, osmosis, cohesion.	Water moves out of the leaves.
Sensitive Plant	Osmosis, turgor pressure	Water supports the plant. Plants use energy.
Balloons in the cardboard, video disc of onion cells in hypertonic, hypotonic solutions.	Osmosis, turgor pressure	Water supports the plant. When there is less water in the plant the plant wilts.

Table 2: Properties of water and plants.

Students' learning was assessed in two ways. First they designed water transport systems using straws, felt, string, and sponges. Students were asked to model what plant structures allow for the movement of water. Designs that were successful moved colored water from the bottom to the top of the system over night. They may also be successful by setting up models in graduated cylinders that show that their model has moved water when the water level drops. Then students wrote about how their model accurately modeled a real plant, and the limitations of their model. The second part of the assessment had students answer problem solving questions about water and how it moves through plants.

The second part of the study focused on the changes that happen in plants during photosynthesis and respiration. All students, with the exception of one, began the unit thinking of photosynthesis as a replacement for respiration. Many of them had an idea that water was food for plants because it was a part of photosynthesis. As a class they were able to come up with the starting materials and the ending materials of photosynthesis. They had few ideas about how those changes occur. More importantly, students could not describe photosynthesis as the way plants convert light energy into chemical energy comparable to the chemical energy humans get from eating. Many came in with the naïve idea that plants make oxygen for us during photosynthesis and because they cannot do respiration.

Rather than focusing on the details of z-schemes of the light reactions and dark reactions the second unit challenges student misconceptions by asking them to think about the matter and energy changes happening during photosynthesis and respiration. Students should walk away from the unit knowing that the carbon in a tree came from carbon dioxide in the air. During the molecular models activity students determine that by using six "waters" and six "carbon dioxides" they are able to make only one glucose and six "oxygens" (see appendix A-11). Each group modeled the starting and ending products made during photosynthesis using molecular models. The limiting factors part of the activity had students start with various numbers of carbon dioxide and water to see how it affected the amount of glucose and oxygen made. Student quickly came up with the idea that the amount of each reactant can limit the final products. We discussed how the models could be used to show light and heat as limiting factors as well. Students struggled on a journal entry about the molecular models activity (see appendix B-6), so we spent more time on photosynthesis. The *photosynthesis disk lab* has students change variables that affect the rate of photosynthesis (Steucek, 1985). This lab also requires a discussion about leaf structure, as student measure the rate of photosynthesis by watching small pieces of leaves float when oxygen is produced.

Students read about early experiments in limiting factors of photosynthesis (Welch, 1968). As a class we discussed some of the details of photosynthesis using overheads of the chloroplast and models of molecules. This tied the photosynthesis disks lab and the molecular models lab together. As students had several lingering questions, we continued to discuss for the remainder of the second part of the unit such as, "How do the molecules actually change inside the plant? Do carnivorous plants have to do photosynthesis? What happens to the glucose after plants do photosynthesis?" The last question about what happens to the glucose after photosynthesis was a perfect link to cellular respiration.

Students did two plant cellular respiration labs. Students designed the first lab around the question, "*Do plants do cellular respiration with the glucose from photosynthesis*?" Most labs measured the production of carbon dioxide by seeds, roots and water plants. Students were familiar with bromothymol blue from previous science classes and developed a variety of ways to see if plants give of carbon dioxide. About half of the groups predicted that plants would not give off carbon dioxide. Students presented their results and concluded as a class that germinating seedlings gave off the most carbon dioxide, roots gave off carbon dioxide, water plants gave off carbon dioxide in the dark. The water plants did not show carbon dioxide emission if the groups left the plants in the light. This led to an interesting discussion because students were claiming that plants cannot respire when engaging in photosynthesis. Students were thinking of respiration as a back up generator.

An interesting way to get at their misconception about plants is to have students brainstorm the possible things that plants can do with the sugar made in photosynthesis. Students cling to the idea that plants cannot respire saying, "If plants do both photosynthesis and respiration how is there any oxygen left for people?"

To help direct their thinking I posed the following questions:

"Do plants do respiration with all of the glucose made during photosynthesis?"

"What do we do with our food?"

Students came up with the ideas that plants may use the glucose for growth, respiration, and food storage. So plants do much more photosynthesis than they do respiration. For every pound of plant, there is quite a bit of oxygen that was not taken in for plant respiration.

Students continued to investigate plant respiration in the *respiration rates in seedlings lab*. This forced students to measure the carbon dioxide evolved from a plant. During the lab one student said, "Wait a minute Ms. Weise, this won't work because plants don't give off carbon dioxide!" The set up for this lab was unique so the student design came from adding an experimental group with one variable to each lab set up. All groups used transfer pipettes stuffed with NaOH soaked cotton (to absorb the carbon dioxide released) and seedlings that rested their tips in a petri dish of water (see appendix B-6). As the seedlings produced carbon dioxide the water moved up the pipettes. Students found that older seedlings respired faster, and the number of seedlings affected the rate of respiration. Also, students noticed that at some point all setups stopped showing an increase in cellular respiration: they were limited by the amount of oxygen in the setups.

The rest of the semester focused on plant life cycles, plant genetics, flowers, mitosis, meiosis, and different phyla and evolutionary relationships in plants. In the plant life cycle unit, students studied mitosis and plant tissues that develop from seeds. The understanding of plant tissues connected well to the study, as tissues are often specialized according to what moves through them. Students used an understanding of plant processes and survival needs to explain why plants need different types of tissues. They also explained why some water plants do not have a need for different tissues. The plant genetics unit looked at Mendelian genetics and modern genetic engineering techniques. On the final exam some students were able to connect all units to purple loosestrife in some way and most students found ways that purple loosestrife connected to most of the units in botany.

Throughout both parts of the study, students worked on an identification book. The book had three sections: plants around the school, plants around your house and wetland plants. Once a week the class worked on their books by either collecting or identifying, organizing and compiling their leaf samples. After visiting the pond, students used drawings and the plant identification books to make their section on wetland plants. The section on wetland plants included only plants found during our field trip to the pond. All students included purple loosestrife in this section.

EVALUATION

This section assesses the new units by using student work throughout the study. When examining student responses on pre-assessments, lab questions, journals and post assessments, improvements in student understanding of the objectives occurred. In general students improved their understanding of plants during the first unit, "What goes into and out of plants". This section will quote student work as evidence of student understanding. In order to present a variety of work different students are used for each student sample. Seven of the twenty-one students were studied in detail by collecting and analyzing their labs, journals and assessments. Two of the seven students represent the high range of the class that had "A" or "B" averages. Three of the seven students represent the mid range of the class that had low "B" through low "C" averages. The two low range students represent the work done by the bottom five students in the class.

Pre-assessments showed that students had naïve ideas such as plants do not respire, water goes in the leaves, and plants do not need energy because they do not move. All students were able to state water was needed for plant survival, but had no ideas why. None of the students had heard of purple loosestrife or considered exotic species an environmental problem. By the end of the unit, all students showed some increased understanding of how plants survive. The assessments used to test student learning were all short answer and essay (see appendix C). Written assessments not only give a more complete picture of student understanding, they allow students to synthesize ideas and learn during the test. Students must practice their skills as writers in all classes as writing cannot be separated from learning (Zeakes, 1989).

When writing explanations students used more scientific language after the units were completed. On the final exam students made concept maps that showed the connections between the general study of botany and purple loosestrife. Several students made important connections that showed a web of understanding that included plant physiology, plant biochemistry, basic plant survival and how they connect to purple loosestrife case study.

By the end of the water unit portion, the best students were able to explain the movement of water in plants using an understanding of the special properties of water. When answering the question from the water test (see appendix B-4), "When you put a straw in water the water only goes up a few millimeters. Plants move water up hundreds of feet. Describe how a drop of water gets from the soil to the leaf of a tall tree." one high range student wrote:

> Plants have bundles of tiny tubes that are like straws, but the smaller the tube the higher the water goes. This is called capillary action. Osmosis is also happening because water is going from a high concentration to a low concentration into the roots and up the stem.

This same student improved his understanding of water movement between the water test and the final exam. He was able to discuss the role of stomata in the leaves, the xylem throughout the plant, and the root hairs. Students had the most success with understanding the environmental and structural factors that change the rate of transpiration. Even on the final exam, which was two months after the water unit, eighteen out of the twenty-one students could explain how different factors affect transpiration rates. When answering the question about transpiration rates (see appendix B-4), one mid range student wrote:

> The xylem is the highway for water, it is how water gets from point A to point B If that highway is destroyed in the stem less water will move through the plant.

Students also scored well on the final exam with a question that asked them to explain how water and oxygen move in plants. They included information about tissues and processes that effect the movement of water and oxygen in plants. Here is on example of how a high range student pictorially showed water movement in plants on the final exam:

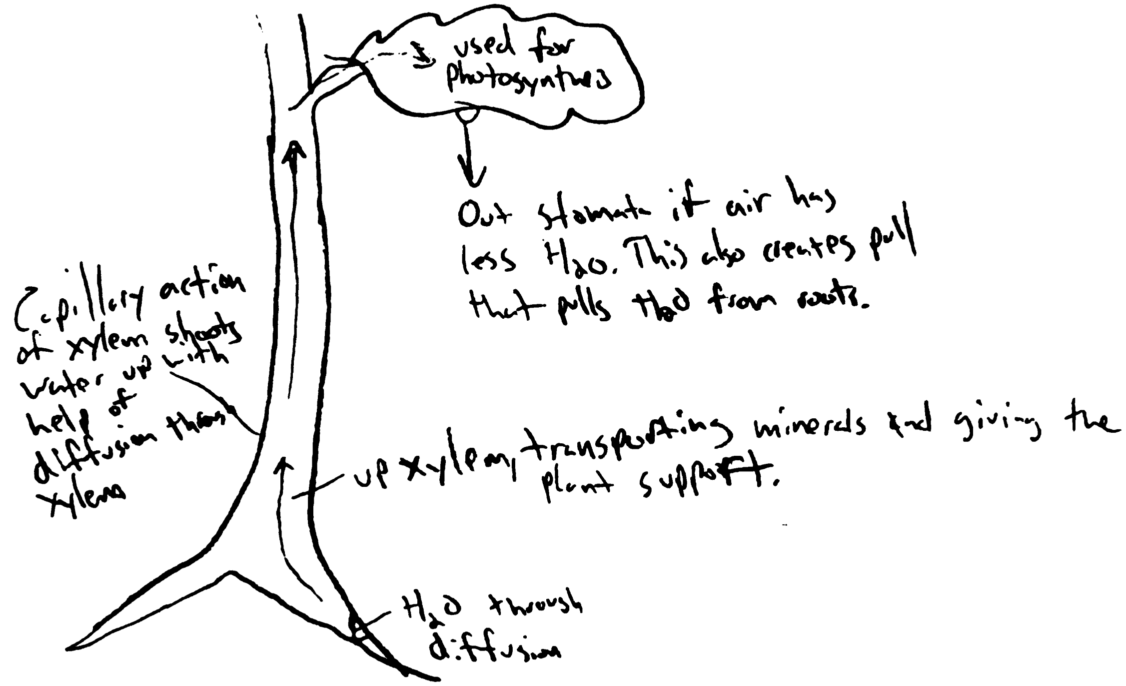


Figure 1: Student diagram of water movement in plants.

By the end of the second, “What moves into and out of plants” unit most students improved their understanding of how matter and energy cycle during photosynthesis and respiration. For, the second test students showed what enters and exits the leaf on a diagram of a leaf cross section (see appendix C-7). Most students showed water coming out of the stomata, oxygen and carbon dioxide going in and out of the stomata and sugar and water in the xylem and phloem. Some students had water going into the stomata for photosynthesis. However, on the final exam all students showed water going in the roots and out of the leaves. By studying the leaf during photosynthesis, students learned about specialized cells in action. They used an understanding of tissues in the leaf to predict what tissues would be in the root and stem. All students drew diagrams of roots and stems with xylem and phloem and epidermal cells. They drew arrows to show water moving up the roots and stems and sugars generally moving down the roots and stems.

Students showed an understanding of how matter changes in plants on test two, which covered photosynthesis and respiration (see appendix C-7). When answering the question, "Suppose there was a special dye on the carbon in the carbon dioxide in the air around a plant. Show on this plant three possible places the carbon could end up and explain how the carbon was transformed in each case?" the seven students had a variety of answers. The two best students showed the dyed carbon in plant leaves using carbon dioxide to make glucose, through out the plant in glucose used for respiration, coming out of the plant as carbon dioxide, in the glucose moving through the plant in the phloem, in the glucose being put in to storage, and throughout the plant in other organic molecules made from photosynthesis. The middle range students drew the dyed carbon going in the stomates as carbon dioxide for photosynthesis, in the glucose being transported in the phloem and stored, and in the glucose being used for respiration. One middle range student wrote,

> It's in the leaves because that is where sugars are made, because there is a lot of chloroplast, and more light energy reaches the leaves. It is in the stem because the glucose doesn't stay in the leaves so, it travels down the stem and some glucose is burned (used for respiration). It's in the roots because the glucose moves down to the roots, then they burn off what they receive since there isn't much glucose in the roots to begin with.

The low range students showed the dyed carbon in the roots, stems and leaves without correctly explaining why the carbon would be found there. They mentioned photosynthesis in the leaf but not respiration, storage or transport of glucose.

Rubrics for four of the main objectives during the two units were used to determine growth in student understanding of concepts. Questions varied slightly between the prior knowledge tests and the post-tests, but asked students to demonstrate an understanding of the same basic objectives. The four objectives assessed by rubrics were: explain why plants need water, explain how water moves through a plant, Explain how plant cells are specialized to carry out specific functions, and use an understanding of cellular respiration and photosynthesis to explain how matter cycles between plants and animals.

<u>Rubrics:</u>

A: Explain why plants need water (Using objective 8,10):

6-Student explains using scientific terminology the way water helps support the plant, transport minerals through the xylem, and is used in the leaves for photosynthesis.

4-Students explain using scientific terminology at least 2 of the ways plants use water.

2-Students explain with out scientific terminology 1-2 of the ways plants use water.

1-Student writes, "Plants need water to live" without explaining why.

B: Explain how water moves through a plant (using objective #3):

8- Students use an understanding of the properties of water, (osmosis, adhesion, and cohesion) to explain how water moves through the plant. Students use names of different plant tissues when describing the movement of water.

6- Students use an understanding of the most of properties of water, (osmosis, adhesion, and cohesion) to explain how water moves through the plant. Students use some of the names of different plant tissues when describing the movement of water.

4-Students explain the direction of water movement with little demonstration of an understanding of the properties of water. Students discuss the roots, stems and leaves with out mentioning tissues.

2-Students explain the direction of water movement, but include water moving into the leaves. Students fail to mention one of the following: mention roots, stems or leaves.

C: Design scientific investigations(constructing objective #3):

6-Students design a controlled experiment that tests an hypothesis related to a real problem. They are specific in their test design so that others could repeat their procedure. The procedure empirically tests their hypothesis.

4- Students design a controlled experiment that tests an hypothesis related to a real problem. They are **somewhat specific** in their test design so that others could repeat their procedure. The procedure empirically tests their hypothesis.

2- Students design an experiment that tests an hypothesis related to a real problem but does not have a control group. Their procedure is not written so that others could repeat their procedure.

D: Use an understanding of cellular respiration and photosynthesis to explain how matter cycles between plants and animals (using objective #13):

8-Students explain correctly how carbon dioxide, water, oxygen and glucose cycle among living things during photosynthesis and respiration. They explain the purpose of photosynthesis and respiration in the plant.

6-Students explain correctly how most of the molecules cycle among living things during photosynthesis and respiration. They explain the purpose of photosynthesis and respiration in the plant.

4-Students explain correctly how some of the molecules cycle between plants and animals during photosynthesis and respiration. They explain the purpose of photosynthesis and respiration in the plant.

1- Students explain correctly how most of the molecules cycle between plants and animals during photosynthesis and respiration. They do not explain the purpose of photosynthesis and respiration in the plant.

The chart that follows shows how students demonstrated their understanding of these four objectives throughout the study. Seven students from the twenty-one students in the class, with a range of abilities were assessed using the rubrics A-D. Each rubric was used prior to the study, at the end of the study, and on the final exam two months after the study. Students are listed from highest to lowest grade in the class. The top two student answers would be similar to the top seven students in the class. The middle three students would be similar to the middle ten students in the class. Finally, the bottom two students would be similar to the lowest five students in the class.

Analysis of student responses using rubrics:

Students: Listed from highest to lowest grade.	Rubric A	Rubric B	Rubric C	Rubric D
1. Pre/post/final	3/5/6	3/7/8	2/*/6	2/8/6
2. Pre/post/final	3/6/6	3/7/8	1/*/5	1/6/8
3. Pre/post/final	2/5/6	2/7/8	2/*/4	1/8/8
4. Pre/post/final	2/4/5	3/6/7	1/*/5	1/8/8
5. Pre/post/final	2/2/4	2/4/6	3/*/6	1/7/--
6. Pre/post/final	2/5/4	2/3/3	2/*/6	1/4/4
7. Pre/post/final	1/2/4	2/3/3	2/*/3	1/4/4
Averages	2/4/5	2.3/5/6.5	2/*/5	1/6.5/6.2

Table 3: Student scores on rubrics A-D.

*This objective was not assessed in tests 1 and 2.

--Student did not answer the question.

According to the final exam all of the twenty students in the class showed growth in their understanding of plants. The objective about matter cycling during photosynthesis and respiration was measured for all students on both the prior knowledge test (see appendix C-5) and the final exam (see appendix C-7). On the prior knowledge tests, all twenty-one students wrote that plants use photosynthesis and animals respire. Class discussions following the prior knowledge test revealed that students either believe that plants do not need to use energy because they do not move, or students believe that photosynthesis is a replacement for respiration. After the photosynthesis unit, one student asked, "What does the plant do with the sugars it makes during photosynthesis?"

This was a nice question to begin our discussion of respiration in plants!

When asked about how matter cycles between plants and animals on test two (see appendix C-7) fifteen students correctly showed plants using both processes of photosynthesis and respiration. By the final exam (see appendix C-8) twelve students drew pictures that showed plants doing both respiration and photosynthesis and animals doing respiration, four students showed that plants do photosynthesis and animals do respiration, and one student wrote that plant respiration only happens in the roots. The remaining students did not answer the question on the final exam. Some student concept maps on the final exams demonstrated a well developed network of ideas about plants and purple loosestrife. Here is an example of how one student made connections on his final exam (see appendix C-8):

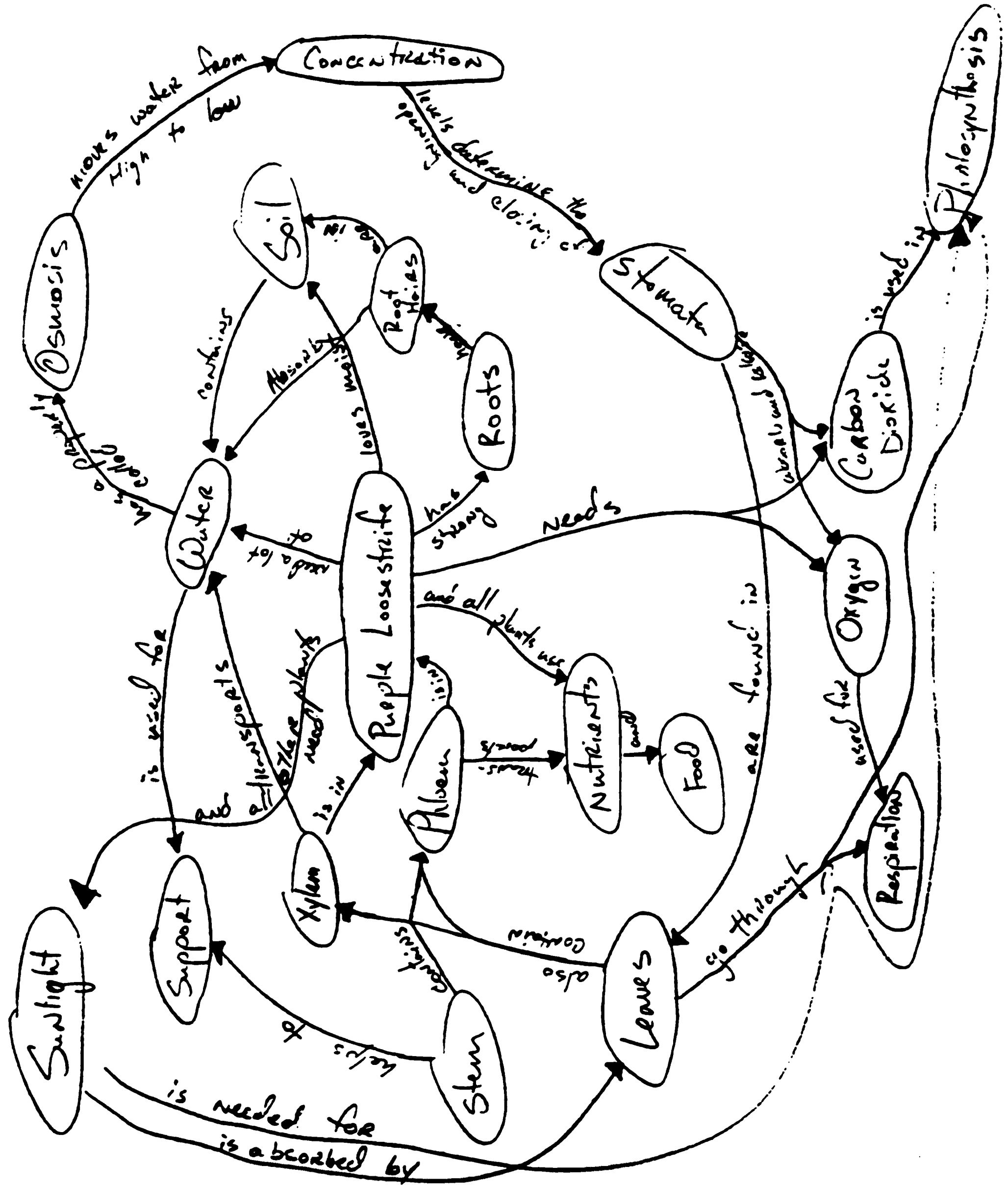


Figure 2: Student concept map of how purple loosestrife connects to Botany.

On the final exam students showed growth in their understanding of the scientific method by designing a lab procedure. Here's how one low range student used the scientific method steps to solve a problem posed on the final exam:

Problem: Do plants use light to convert carbon dioxide from the air into glucose?

Gathering Information:

-Plants use light to make their own food (photosynthesis)

-Plants take in carbon dioxide and give off oxygen.

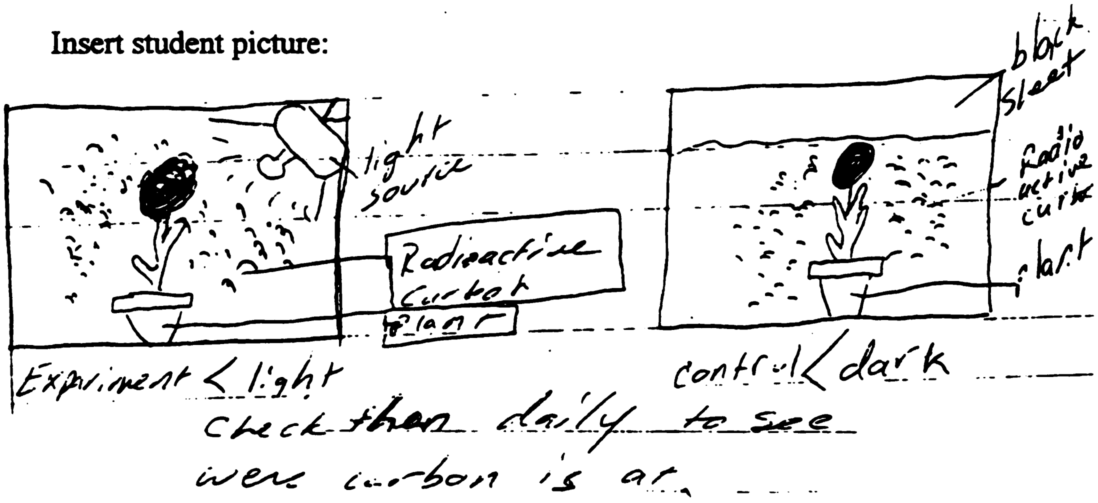
-Plants can store the glucose.

Hypothesis: I believe plants use carbon dioxide from the air and convert it to glucose.

Set up:

1. Take radioactive carbon and place it in the air around our experimental plant in the light.
2. Our control will be in regular night conditions, and also have the radioactive carbon.

Insert student picture:



Check than daily to see were carbon is at.

Figure 3: Student diagram of experimental design.

Several students developed experiments that demonstrated an understanding of proper lab procedures and photosynthesis. Most students designed control groups and tested only one variable with their procedures. The best students had excellent detail in their experimental protocols. Following is one experimental procedure from a high range student:

Problem: Do plants use light to convert carbon dioxide from the air into glucose?

Gathering Information:

-Carbon dioxide has carbon in it.

-radioactive carbon would show where its been because its anatomically unstable.

-plants give off oxygen.

Hypothesis: Plants do convert carbon dioxide in the air into glucose.

Experiment:

1. Obtain a green plant of any kind.
2. Place in a large sealed container with plenty of water.
3. Suck all air out of box and replace it with radioactive carbon and normal oxygen.
4. Place box in an area where there's plenty of sunshine.
5. After a day or two take a cross section of a leaf and check for the radioactive carbon.
6. Check the glucose molecule for radioactive carbon.

The final exam also showed exciting progress on countering the misconception that plants eat soil somehow. On the prior knowledge questions all students thought that plants take in water and nutrients through the roots. Student compared these nutrients to the food that people consume. One middle range student with a "C" average wrote:

> It is impossible for plants to take protein and other food molecules in through the roots because they are too big to fit through the selectively permeable epidermis cells of the roots.

Also, when asked about what people consume that is comparable to fertilizer on the final exam, students gave the following answers (Please note, some students did not answer the question): two students compared fertilizer to food, 13 students compared fertilizer to vitamens and minerals, and two students compared fertilizer to food and vitamins. Students that included food as something that goes in the roots all said in the first part of the question that food was too large to go across cell membranes. This discrepancy indicates an incomplete understanding of the energy and matter conversions.

DISCUSSION AND CONCLUSION:

The purple loosestrife case study began to address the problems of low student interest, few real-world connections and lack of student experimental design in the botany class. This purple loosestrife study engaged students in a real problem and challenged them to generate scientific questions and scientific ways to answer their questions. Students acted as a community of scientists solving a problem, as they worked in groups, designed labs, and presented them to each other. They were motivated to learn about plants because it helped them solve their central problem of purple loosestrife taking over Michigan wetlands. Students easily came up with the idea to use biological control, but wanted to find out more ways to control purple loosestrife. On a field trip to MSU to see the beetles being raised by the Purple Loosestrife Project, one student remarked with pride, "Hey, we came up with that in class! The idea of using beetles from Europe, that was our idea too!"

In general all students had the opportunity to make progress in their understanding of plants during the purple loosestrife case study. As with all high school classes there was a range of success that corresponded with student effort and student attendance. All students, even those who failed botany showed growth in their understanding of plants on the final exam. The middle range and high achieving students made exciting connections about plants. In the lab students showed growth in their use of the scientific method from the first experiment to the experiments they designed on the final exam. They used control groups and detail more consistently and asked thoughtful questions of each other during presentations of labs.

The best part of the new unit was an emphasis on student lab design. Students rose to the challenge of generating wonderful problems and experiments. The *transpiration in bean plants lab* was successful for all groups! Not all groups observed the expected results, but all groups observed water movement and were able to present their results clearly to the class. Students practiced the art of analyzing and improving procedures. They learned that real science has unexpected outcomes and constantly tackles new problems. While unexpected results can be disappointing, they are real science and lead to new questions.

Some groups were disappointed with their experiment that addressed the problem, *How does the environment affect purple loosestrife?* A couple of the designs had no growth of their root balls. This will continue to happen because some students may decide not to water their plants! Again, unexpected results led to more real science. As a class, students expressed ideas like, "We should use more plants, I should have watered my plant more, we should try other wetland plants, we should look at other experiments!"

This lab could be improved by having the students gather more information on previous experiments using loosestrife, using more plants during the experiment, and using a different wetland plant as a comparison. One way to decrease the number of non growing root balls that do not grow is to have students start their experiments with young plants that have already shown some growth. Each student experiment could use more than two plants. Also, more time should be spent researching past labs done on purple loosestrife for background information. Using previous labs would give students more ideas about how to design and implement their experiments. Students could then turn in a more formal lab report. I would like to see these lab reports done in several high schools, so students across the state, working with the Purple Loosestrife Project could learn from each other.

Even when lab procedures were described to them, students were encouraged to come up with their own variables and ways to test them. For example, in the photosynthesis disk lab two groups wanted to test the effect of temperature on the rate of photosynthesis. Each group came up with a different way to test this. One group heated the water that the disks were floating in and the other put the entire set up in a water bath. The heated water damaged the cells in the group that did not use a water bath. They decided that the other procedure was better and lowered their temperature slightly when they tried the lab a second time.

One of the most diverse set ups among groups were those testing to see if plants respire using bromothymol blue (BTB). None of the six experiments were alike. Some groups tested small plants, others used seeds or seedlings. One group tested roots by putting the roots of small plants into test tubes that had water and BTB in them. One group tested seeds by putting seeds directly into BTB. The group that tested leaves put elodea into test tubes in the light and in the dark. Unfortunately, this final set up led students to make the conclusion that respiration happens only when plants can't engage in photosynthesis. Class discussion about what these results mean did not counter the idea. An experimental way to show both photosynthesis and respiration happening at the same time would help! Another way counter the notion of respiration as a back up generator when plants do not have light for photosynthesis is to have students work out problems together that force them to think about why plants must use both photosynthesis and respiration. Only the student with a solid understanding of the purpose of both processes can accept the idea that plants need to engage in both photosynthesis and respiration.

The lab on structures of plants involved in water transport could be improved by making it more problem centered. As the lab is written students examine and draw microscopic structures in plants. The students could investigate related problems such as:

> How does the structure of purple loosestrife help it survive in the wetland?
>
> What structures insides plants are used for water movement?
>
> What common structures do purple loosestrife and other plants have?

Comparing purple loosestrife to another plant would put more emphasis on the specialization of wetland plants. Students could use the microscope to solve problems by comparing the number of stomata on a purple loosestrife leaf and a non-wetland plant leaf. They could predict which tissues and structures would be used to move water and which ones are used for protection.

Another problem with the unit is the section on identifying wetland plants and purple loosestrife. We collected kinds of plant specimens once a week throughout the unit.

While this was going on, students were doing long term labs on purple loosestrife and bean plants. Many students had trouble focusing when we had several long-term projects going on at once.

Starting the semester identifying purple loosestrife and wetland plants would work better. Students could complete their plant identification books and assess the pond that has purple loosestrife before starting the unit about materials moving in and out of plants. This is a good place to work on the state objectives for classification and evolution taught after the study. Adding an emphasis on classification and evolution would make the identification book more appropriate for the high school level and help students understand how the special adaptations of wetland plants. This would eliminate the confusion with several long-term projects, and give students more background information for their student designed labs. The trip to the pond could also be used to collect root balls for the student designed lab in class.

Students worked hard during the group portion of the water unit test. They focused in their groups for a solid hour as they designed model plants. Several of them thought about properties of water when designing their experiments. Most groups tried to show roots absorbing water, stems transporting water and flat leaves. One group experimented with their model by making the stem out of four straws. They were not sure which materials would work the best so they designed each straw with different materials inside leading to a model felt leaf. They hypothesized that one straw would move more water. The next day two of their leaves were red with food coloring indicating water movement.

It would be interesting to determine just how high these designs could move. Students were excited the day after this portion of the test and came in to immediately look and see if the water moved in their set ups!

By the end of the portion of the study on water movement, most students explained that plants use water for support, movement of nutrients through the plant and photosynthesis. Students had great success working with factors that effect the rate of transpiration. Although all students drew water going into the roots up the stem and out of the leaves on the water test, some students still showed water going into the stomata on the prior knowledge questions for the second part of the unit! This shows a missing link in their understanding of the physical properties of water. In a class discussion following the prior knowledge questions, several students pointed out the difficulty in getting water in the stomates! By the end of the second unit most students showed water getting into the leaves through the xylem and not the stomata.

Student understanding of the movement of materials through plants seemed to improve after a unit on tissues. When comparing algae to a leaf cross section students were able to explain why the algae did not have a need for the tissues found in a leaf. Students were asked to show the tissues in one part of the plant and to then show how materials move through that part of the plant on the final exam. Students were able to draw the tissues and show where water, carbon dioxide, oxygen and glucose would be found and how they could move in a plant.

The most frustrating lab for students was the *photosynthesis disks lab*. Students had trouble getting the disks to sink at the beginning of the lab. They learned valuable lessons about experiments taking persistence and engineering. However, too much class time was spent on these disks and students did not gain much understanding of photosynthesis and limiting factors. After a week on limiting factors, I decided not to have students do *the photosynthesis rates in purple loosestrife lab* I developed with Ken Nadler from summer 1999. This lab has students place in a plastic disposable pipette with cotton soaked in sodium bicarbonate. When these pipettes are placed in the light they give off oxygen and an air space forms in the pipette (see appendix A-7). A larger air space means more oxygen is being produced and photosynthesis is occuring. Next time I will have students design experiments on rates of photosynthesis using *the photosynthesis rates in purple loosestrife lab* instead of *the photosynthesis disks lab.*

As the student concept maps indicated the purple loosestrife problem can be used to connect the entire semester of botany. One group of students kept their purple loosestrife alive until it flowered in class, opening up the possibility to use them as a way to study flowers. Purple loosestrife plants are easy to grow in the classroom. They grow quickly and respond to changes in their environment. Root balls can be found all over wetlands in our area and grow easily when properly watered in the classroom. When students are involved in the purple loosestrife problem they are involved in solving a current environmental problem.

Despite a need for some modifications in a couple labs, this unit was successful. It encouraged students to act as scientists and learn about plants. The purple loosestrife case study focused on fewer objectives and more depth of student understanding. The case study could easily tie into the second half of the semester. Parts of the unit and some of the labs would fit well into any general biology class. General biology classes could use the labs on photosynthesis and respiration, and the student directed experiments. The purple loosestrife case study is an interesting ecological phenomenon to examine in any biology class. Even after we were formally done studying purple loosestrife, students mentioned the plant throughout the semester. They asked if purple loosestrife could be genetically engineered to make something useful or if it already has some value to ecosystems. It was nice to see students generating thoughtful solutions with genuine interest in an environmental problem. After all, if we do not teach students to care about the science in their world, why teach them science at all?

APPENDICIES

APPENDIX A

Objectives

APPENDIX A

Objectives fir teaching botany based on purple loosestrife case study: As with the Michigan Essential Goals and Objectives for Science Education, these are divided into constructing, reflecting and using objectives.

CONSTRUCTING: These objectives teach students to use the scientific method when solving problems.

1. Develop questions or problems for investigation that can be answered empirically (MEGOSE #13).
2. Suggest empirical tests of hypothesis (MEGOSE #14).
3. Design and conduct scientific investigations (MEGOSE #15).
4. Gather and synthesize information from books and other sources of information (MEGOSE #19).

REFLECTING: These objectives teach students to analyze their own learning and the claims of others.

1. Justify plans or explanations on a theoretical or empirical basis (MEGOSE #11).
2. Describe some general limitations of scientific knowledge (MEGOSE #12).
3. Discuss the historical development of key scientific concepts and principals (MEGOSE #14).

USING: These objectives contain the information and new concepts in the new unit.

1. Explain how essential materials move into cells and how waste and other materials get out (MEGOSE: Cells #10).
2. Explain how different concentrations affect the movement of water across a membrane.
3. Describe how water travels from the soil through the plant and out of the leaves.
4. Describe how nutrients diffuse across root cells and up to the leaves.
5. Explain how different concentrations affect the movement of substances across a cell membrane (for example, absorption of water and nutrients by plant roots).

6. Classify cells/organisms on the basis of organelle and/or cell type (MEGOSE: Cells #5).
7. Compare and contrast ways in which selected cells are specialized to carry out particular life functions (MEGOSE: Cells #7).
8. Explain the process of food storage and food use in organisms (MEGOSE: Living Things #12).
9. Compare the transformations of matter and energy that occur during photosynthesis and respiration (MEGOSE Cells #9).
10. Explain that carbon that makes up plants originated in atmospheric carbon dioxide.
11. Explain how cells convert food energy into energy cells use for life processes (ATP).
12. Use an understanding of cellular respiration and photosynthesis to explain how matter cycles between plants and animals.

APPENDIX B

Activities

APPENDIX B-1

Water Loss in Plants:

Description: Students measure the amount of water a plant looses daily by weighing a plant that has a bag around the soil so that the only water that escapes goes out of the leaves. This procedure is simple enough that students should be able to design the procedure as an answer to the problem, "How do plants take in water?"

Using Objectives:

→Explain how essential materials move into cells and how waste and other materials get out.

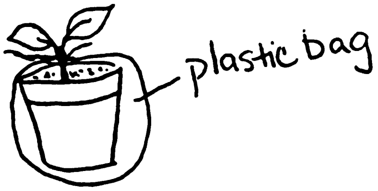
→Describe how water nutrients diffuse across root cells through the stem and out of the leaves.

→Explain how different concentrations affect the movement of substances across a cell membrane (for example, absorption of water and nutrients by plant roots).

Procedure:

1. Water a small purple loosestrife plant (approx. 8in plastic pot) and let the water drain until it stops dripping...geraniums work well too! You may be able to get small purple loosestrife plants using small cuttings from other loosestrife root balls. Purple loosestrife plants often have several shoots coming off of the root. You may have to put holes in a plastic bag to allow for each shoot.
2. Put a plastic baggie over the pot and tape it closed around the stem so that the only water that escapes goes out of the leaves.
3. Weigh the plant every day for a week.
4. Possible variables: number of leaves on the plant. wind environment, temperature, humidity (put a plant into a closed chamber like a 2 L bottle), coat the bottoms or tops of leaves with vaseline, light vs. dark, salt concentration in soil by watering with salt water, stomatal density of different plants.

5. The finished plant should look like this:



Conclusion questions:

1. How can the change in the mass of the plant over the past week be used to explain how plants transport water?
2. If you could somehow track a water molecule from the watering can into your set up where would that water molecule go?
3. Is there more than one possible answer for question #2? Explain why.

Adapted from Ken Nadler & Plant Biology Science Projects-Hershey

APPENDIX B-2

Water Tricks:

Description: Students observe the properties of water at several different stations. They write about how those properties of water affect water movement in plants.

Using Objectives:

- →Explain how essential materials move into cells and how waste and other materials get out.
- →Describe how water nutrients diffuse across root cells through the stem and out of the leaves.
- →Explain how different concentrations affect the movement of substances across a cell membrane (for example, absorption of water and nutrients by plant roots).

Procedure: At each station describe what happens. Then explain what this event tells you about water. At the end of the lab students write a summary about how the properties of water effect water movement in the plant.

1. Toothpick Star: When a drop of water is added to four bent toothpicks, they expand making a star. (capillary action, osmosis)
2. Floating Paper Clip: When carefully placed, a paper clip floats on top of water. (surface tension)
3. Raindrops keep falling on my Penny: Students put drops of water onto a penny until the water spills off. (surface tension, cohesion)
4. Straw Power: Tubes with various diameters are put into a petri-dish with water. Skinnier tubes have water the moves up farther. (capillary action, adhesion)
5. Sweaty Leaf: A bag is placed over a leaf at night. The bag collects the water coming off of the plant. (transpiration, evaporation)
6. Screen Saver: A screen is glued onto a cup. When turned upside down the water does not come through the screen. If the student touches the screen water leaks out. (cohesion, adhesion)

Summary Question: How do the properties of water demonstrated by the stations affect water movement in plants?

Resource: "What variables are affecting the growth of plants". Invitations to Science Inquiry. Pp. 409-428. Science Inquiry Enterprises. 1987.

APPENDIX B-3

Transpiration Rates Lab:

Description: Using bean or sunflower seedlings test the amount of water taken up by different parts of the plant by putting them in a graduated cylinder filled with water.

Constructing Objectives:

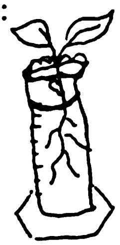
- →Suggest empirical tests of hypothesis.
- →Design and conduct scientific investigations.

Using Objectives:

- →Explain how essential materials move into cells and how waste and other materials get out.
- →Describe how water nutrients diffuse across root cells through the stem and out of the leaves.
- →Explain how different concentrations affect the movement of substances across a cell membrane (for example, absorption of water and nutrients by plant roots).

Procedure: We work on this general procedure as a group. Students come up with the ideas readily as the set up makes sense! Each group tested different variables using at least 2 set ups. All groups came up with pretty much the same way to set up the transpiration tubes.

1. Fill 2 graduated cylinders within an inch from the top. Record the water level.
2. Put the roots of the plant completely in the water.
3. Seal the top of the cylinder with clay.
4. Record the amount of water in the cylinder at the end of the hour, and the next day.
5. Here is a diagram of one student set up:



Reference:
Biological Sciences Curriculum Study. "Investigating Transport in Plants". Biological Science: Molecules to Man. Pp. 474-475. Houghton Mifflin Co. 1968.

APPENDIX B-4

Parts of the Plants that affect Water Movement Questions:

Directions: Use the book and your water movement article (Miller et. al., 1993) .

1. Roots (pg 344-345):
    a. Explain how the structure of roots allow for the absorption of water.
    b. Why is it impossible for roots to absorb food (sugars, fats, proteins) from the soil?
    c. What can roots absorb besides water?
    d. What causes root pressure?
    e. Why do roots have to do active transport?
2. Stems (pg 352):
    a. How are materials translocated in the stem?
    b. How does the structure of the stem allow for the movement of water?
    c. Describe the cohesion-transpiration theory.
3. Leaves (pg 363-364):
    a. Describe how leaves allow for transpiration and guttation.
    b. What evidence for transpiration have we seen in the lab?

APPENDIX B-5

Lab: Roots, Stems and Leaves…Structures involved in water transport.

Description: Examine, label and compare the internal structures of prepared slides and purple loosestrife slides.

Using Objectives:

→Describe how water nutrients diffuse across root cells through the stem and out of the leaves.

→Compare and contrast ways in which selected cells are specialized to carry out particular life functions.

Procedure: Follow the instructions for each plant part. Please label all sketches with the power you used and the name of what you are sketching. **Please make all drawings large and in pencil!**

Roots:

1. Draw a picture of a root from the prepared slides.
2. Prepare your own slide of a purple loosestrife root **cross section** using a razor blade and methylene blue.
3. Label both sketches with the following structures: **xylem, epidermis, root hairs**.

Stems:

1. Draw a picture of a stem from the prepared slides.
2. Prepare your own slide of a purple loosestrife stem **cross section** using a razor blade and methylene blue.
3. Label both sketches with the following structures: **xylem, epidermis**.

Leaves:

1. Prepare a slide of the under layer of a Coleus leaf with the methylene blue.
2. Prepare a slide of a small purple loosestrife leaf using a razor blade and methylene blue. Pur the underside of the leaf up!
3. Draw both specimens and label both sketches with the following structures: **stomata, guard cells, and epidermal cells.**

Questions:

1. Stomata:
    a. Why would you expect to find stomata in leaves but not in roots?
    b. Why is it important for plants to control the opening and closing of these holes and not leave them open all of the time?

2. Explain why all three structures have epidermal cells. What might the function of the the epidermal cells be?
3. You did not sketch the xylem in your leave drawings.
   a. Where in a leaf would you expect to find xylem?
   b. Why would a leaf have to have xylem?
4. Compare the stem from the prepared slide to the purple loosestrife slide. Describe and explain the differences.
5. Compare the stomata in your two leaf slides. What differences do you notice. Explain what differences in stomata means for the plant and what environmental conditions are best for that plant.

APPENDIX B-6

How do materials get into and out of Purple Loosestrife?

Respiration in seedlings (How much carbon dioxide is given off by seedlings?):
Description: Put ten germinating seedlings into a plastic pipet with NaOH soaked cotton. NaOH takes up carbon dioxide ($NaOH + CO_2 \Rightarrow NaHCO_3$). When the bottom of the pipet is put in a petri dish of water the water moves up the pipet as the carbon dioxide is made. The more carbon dioxide made the higher the water moves up the pipet. Amounts of carbon dioxide made can be compared if the pipets are marked using a ruler and a permanent marker.

Objectives:

- Explain how cells convert food energy into energy cells use to grow.
- Use an understanding of cellular respiration to explain why plants give off carbon dioxide and take in oxygen.
- Design and conduct scientific investigations.

Materials:

- Plastic pipets (at least two per group of students)
- 1% NaOH solution (1 gram NaOH + 100ml of distilled water)
- Cotton (one cotton ball per group of students)
- Germinating seedlings (20 per group of students)
- Petri dish (1 per group of students)
- Styrofoam from an egg carton or meat tray (1 per group of students)

Procedure:

1. Cut off the tips of plastic pipets so that there is a wide opening.
2. Put 5 drops of a 1% solution of NaOH each pipet.
3. Stuff dry cotton in the pipet so that the cotton absorbs all of the NaOH and the NaOH solution will not touch the seedlings.
4. Add 10 germinating seedlings to two pipets.
5. Leave one pipet as a control without seedlings or with killed (boiled) seedlings.
6. Put the pipets into a styrofoam stabilizer and set them on a petri dish that is half filled with water. Please see the diagram A-1.
7. The rate of water uptake can be measured with in 30 minutes. If these are left over night is possible for the water to go up the pipet a couple of inches. At some point the water stops when the seedlings run out of oxygen!
8. Record movement of water up the pipets in a data table.
9. Possible variables to test: age of seedlings, types of seedlings, amount of seedlings.

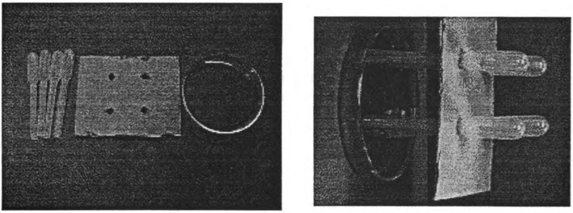


Figure B-1: Respirometer materials and experimental design.

Questions:

1. What was the movement of water up the pipette used to measure?
2. Why does the movement of water eventually stop?
3. How could you set the experiment up so that the amount of water moving up the pipet:
    a. 1. Moves faster. 2. Moves higher. 3. Stops earlier.
    b. Now explain why your solution would work in each case.
4. What are the seedlings using during cellular respiration? Where did the seedlings get the materials that they are using?
5. Draw a picture of a seedling that shows what goes into and out of the seedlings when they use cellular respiration.
6. What other questions could you answer using the same set up?

APPENDIX B-7

Photosynthesis rates in purple loosestrife:

Description: Students study how different things affect the rate of photosynthesis using plant leaves and disposable plastic pippettes.

Procedure:

1. Soak cotton in a 4% sodium bicarbonate solution.
2. Stuff the cotton into a plastic pipette with the end cut off.
3. Stuff 3 purple loosestrife leaves into the pipette.
4. Put the pipette into a petri-dish filled with water.
5. Suck water up the pipette so that it fills the skinny part of the pipette.
6. Mark the water level and observe (this will need to be left over night).
7. Students should be given the general set up and then make up possible variables to test using the set up. They can test several limiting factors by covering the bulbs of the pipettes with different colors, different temperatures, various concentrations of sodium bicarbonate, and other student ideas.
8. Most set ups look like the following diagram:

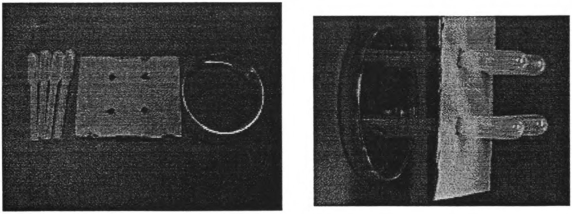


Figure B-2: Materials and design for *photosynthesis rates in purple loosestrife lab.*

APPENDIX B-8

Lab: Digestive enzymes in seedlings:

Description: Using seedling extracts test for the digestion of starch, protein and fat. This has worked so far with beans, radishes, and lettuce of various ages!

Constructing Objectives:

→Develop questions or problems for investigation that can be answered empirically.
→Suggest empirical tests of hypothesis.
→Design and conduct scientific investigations.

Using Objectives:

→Explain the process of food storage and food use in organisms.
→Explain how cells convert food energy into energy that cells use to grow.

Procedure:

Part One:

1. Make enzyme extract from seeds: grind 7 seedlings in 20ml of water using sand and a mortar and pestle.
2. Filter the extract using filter paper and a funnel.
3. Put 5 ml of a starch solution in a test tube.
4. Put 4 drops of Iodine in your solution (this should turn ____________)
5. Put 2 drops of your filtered seed mush into the test tube.
6. Record observations of time and color change.

Part Two: On a separate sheet of paper, design a related experiment using a different problem about seed digestion. Please use the lab format using the 6 steps. Check with me before you set up the lab. Be prepared to present your procedure and results to the class.

→Your conclusion for this lab should include a BRIEF summary of what all groups found out about seeds and digestion. Also, explain why our results make sense in terms of what seeds need to do to grow in plants.

APPENDIX B-9

Digging up and potting purple loosestrife:

Description: Using a sturdy shovel, old boots, and a wetland plant guide book, students dig up root balls and plant them in the classroom. Students use the roots to investigate student-generated problems (see scientific method check list).

Procedure (keep in mind you are dealing with an exotic species, do not spread the problem further by dispersing seeds. Also dispose of purple loosestrife when your experiments are complete by letting them rot in a black plastic bag and throwing them away! **DO NOT COMPOST OR THROW AWAY CARELESSLY**):

1. At the site identify purple loosestrife (see references below).
2. Plants near the river or very wet soil are easier to dig up.
3. Cut off the dead stems of a purple loosestrife plant.
4. Dig up the entire root of a plant. This is the part you take to the classroom.
5. Fill up a bucket with enough roots for your classroom experiments.
6. Planting:
    a. Use pots big enough for each root.
    b. Fill the pots half way with soil.
    c. Add a small spoon full of fertilizer pellets.
    d. Add more soil.
    e. Add your root.
    f. Add more soil.
    g. WATER, WATER, WATER, WATER, WATER. You will need to water the bejeebers out of these plants. Remember they are from a wetland and will grow better in wetland conditions. Students that want to investigate how the amount of water affects the growth of purple loosestrife need to be aware that these plants need to stay moist! I water them so that there is standing water in the base of the pot (I know you are not normally supposed to do this with plants!)
    h. See figure one for what planted 10 day old roots look like in one experiment:

References:

Hoagman, W. H. 1998. Great lakes wetland plants: a field guide. Ann Arbor: Michigan Sea Grant Publications. 170pp.

Klepinger, M. 1999. The purple loosestrife cooperators handbook. East Lansing: Michigan Sea Grant Publications. 517. 355. 5508. klep@pilot.msu.edu

United States. USDA Soil Conservation Service. Midwestern Wetland Flora. n.d.

Figure B-3: Picture of potted purple loosestrife.

APPENDIX B-10

Scientific Method Check List ; Please be sure you have a complete lab by using the following check list!

PROBLEM:

_____ Is specific and stated in the form of a Question?

INFORMATION:

_____ Information is specific to the problem

_____ Information is factual and objective

HYPOTHESIS:

_____ A statement which answers the problem

_____ Uses the information to specifically address the problem.

TEST:

_____ Tests the hypothesis

_____ Tests only one variable

_____ Has a control group and an experimental group

_____ Describes in detail the procedure so that others could repeat the experiment

RESULTS:

_____ Only observations -- no inferences or assumptions

_____ graphs, charts, photos, drawings, sketches, ...

ANALYZE AND CONCLUDE:

_____ Restate the hypothesis

_____ Brief description of test and results

_____ analyzes why the test confirmed or did not confirm your hypothesis.

_____ Uses specific evidence from the results to explain what happened.

_____ explains what would be changed for the next time the experiment is performed

APPENDIX C

Assessments

APPENDIX C-1

Prior Knowledge Questions:

A - Purple Loosestrife:

1. What have you heard about purple loosestrife?
2. Have you ever seen purple loosestrife near our school?
3. Describe why exotic species are an environmental problem.

B - General Plant Questions:

1. What are the characteristics of a plant? How do you decide if something is a plant or not?
2. List as many things that you can think of that happen in your day that connect you to plants:
3. If you looked at a plant under a microscope what would you see?
4. If you had to make fertilizer for your plant, what ingredients would you include?

C - Scientific Method:

1. Write the basic steps of the scientific method. What is the purpose of each step?
2. Describe the characteristics of a GOOD lab design.

D - How does a seed become a plant?

1. What materials would you expect to find in a seed? Or if you had to make a seed, what ingredients would you need to put in?
2. Are seeds alive? Explain your answer.
3. Draw a picture of what happens to a seed as it becomes a plant.

E - How do materials move into and out of plants?

1. Make a list of all of the materials that go into a plant:

2. Make a list of all of the materials that go out of a plant:
3. Which of the materials listed in # 1 and # 2 do you consider food?
4. Explain what happens to the materials that go into the plant.
5. Draw arrows and words on the plant that is on one of the overheads to show where all of the materials listed in # 1 and # 2 enter and leave the plant.

F - Plant Genetics:

1. Explain the relationship between flowers and seeds.
2. Describe some ways that plants have been genetically engineered to benefit humans.
3. How does genetic information get passed on from the parent plant to it's offspring?
4. How would changes in a population of plants arise?

APPENDIX C-2

Water Journal:

1. Would it be possible for a tree to survive if the rain never hit the leaves? Explain why.

2. A. Describe one hypothesis scientists use to explain how water moves up plants.
   B. What special properties of water support this hypothesis?

3. Give two reasons why plants need water.

4. Explain why leaves wilt.

APPENDIX C-3

Design a system that demonstrates the cohesion/tension theory of water movement:

Description: Students will be asked to model what plant structures allow for the movement of water. They can choose materials and plant design. Designs that are successful should move colored water from the bottom to the top of the system over night. They may also be successful by setting up models in graduated cylinders and showing that their model has moved water.

Procedure:

1. Using felt, sponges, clear tubing, string, and straws of different diameter design and build a simple root, stem, leaf set up. Try to make a set up that will take up the most water the fastest.
2. Put the model plant into a 50ml graduated cylinder that has water up to the highest mark when the model plant is in the cylinder.
3. Leave the plants over night and see which ones take up the most water.
5. You can try different controlled set ups to see which factors affect water uptake by plants: change humidity, wind, size or number of leaves, number of fake vascular bundles

Sample Student Model:

APPENDIX C-4

Botany: Water Test

I. **Group Portion:** Students designed a system described in Appendix B-3.

II. **Individual Portion:** Answer all questions using complete sentences, when needed.

1. (6 points) Give three reasons why plants need water.
2. (3 points) Purple loosestrife:
   a. Explain why purple loosestrife is an environmental problem.
   b. Explain how purple loosestrife became an environmental problem in the US.
   c. How can you identify purple loosestrife?
3. (8 points) Predict what would happen to the water level in the graduated cylinders after 24 hours if the plant were in the conditions below. Assume a plant that had roots, stems and leaves intact had the water level decrease by 2ml.
   a. Write your prediction below each picture.
   b. Draw on each picture the path that the water in the graduated cylinder would take.
   1. A plant with out roots
   2. A plant without leaves
   3. A plant in the sun
   4. A plant with Vaseline sealing the surface of the leaves.
4. (2 points) How could you make the water in the graduated cylinders go down faster with out changing the structure of the plant? Explain why this would work.
5. (4 points) Roots:
   a. Explain how the branching structure of roots allows for water absorption.
   b. How does water enter the root hairs and the epidermal cells?
6. (3 points) Explain why the plant in the bag, that covered the pot so that no water evaporated from the pot, weighed less after several days.
7. (3 points) Adding fertilizer to your plants changes the concentration of water in the soil. If you add too much fertilizer there is a higher concentration of water in the plant than there is in the soil. What will happen to the water in the roots with a plant that is over fertilized. Explain your answer.
8. (10 points) When you put a straw in water the water only goes up a few millimeters. Plants move water up hundreds of feet.

   a. Describe how a drop of water gets from the soil to the leaf of a tall tree.
   b. Explain what special properties of water allowed that movement of water to happen.

9. (5 points) Draw arrows on the following plant that represent all of the ways that water moves into and out of plants.

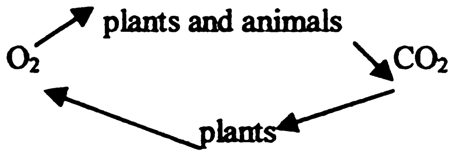
APPENDIX C-5

Part Two: Movement of gases and food in purple loosestrife.

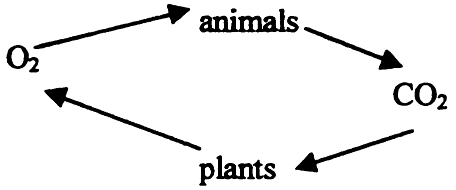
Prior Knowledge Journal:

1. Roots:
   a. What do plants take in from the soil?
   b. What do they use each thing listed in 'a' for?
   c. What do roots give off?
2. Leaves:
   a. What goes in and out of stomata in the leaves?
   b. Why would the plants open their stomates?
   c. Why would plants close their stomates?
3. What goes in and out of stems?
4. Which of the following accurately represents the gas exchange between plants and animals: Write the letter you choose, then explain your choice.

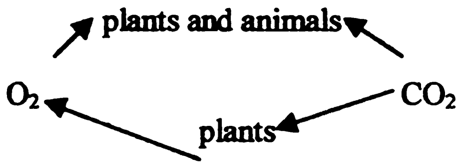
a.



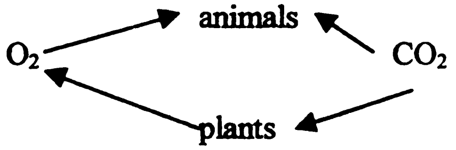
b.



c.



d.



APPENDIX C-6

Journal Questions about activity:

1. What are the starting materials for photosynthesis?

2. Draw on the following leaf (INSERT A LEAF CROSS SECTION) where the starting materials come from:

3. What does the plant make when it does photosynthesis?

4. What happens to the products of photosynthesis? Draw on the following leaf where the products of photosynthesis go:

5. What various conditions did we model in class?

6. Describe how the amount of light change the rate of photosynthesis?

7. How could we model using only red light with our class?

8. Describe how temperature affects the rate of photosynthesis?

9. How could we model increasing the temperature with our class?

10. Use the following Carbon Dioxide graph (USE A GRAPH THAT SHOWS THE LIMITING FACTOR OF CARBONDIOXIDE) to answer questions a-c:
    a. Explain why a plant that had 0.05 percent carbon dioxide would have a higher rate of photosynthesis than a plant that had 0.01 percent carbon dioxide.

    b. Use the graph to predict how the rates of photosynthesis of the following plants would compare: a plant with 0.07 percent carbon dioxide, a plant with 0.1 percent carbon dioxide and a plant with 0.15 percent carbon dioxide.

c. Explain the flat portion of the carbon dioxide graph.

APPENDIX C-7

Test #2: What goes into and out of plants?

1. List all of the materials that go into plants.
   a. Write why each of these materials goes in.
   b. What happens to these materials while they are in the plant?

2. Use arrows to draw on the following leaf all the ways water, carbon dioxide, ocygen and sugar move in relation to the leaf.
3. If you take a log and burn it in the fireplace you end up with a black chunk left over. That black left over is carbon. How did the carbon atoms get in the tree?
4. Suppose there was a special dye on the carbon in the carbon dioxide in the air around a plant.
   a. Show on this plant 3 possible places the carbon could end up.
   b. Explain how the carbon was transformed in each case.
5. When the concentration of carbon dioxide is the same in side the leaf as it is outside of the leaf, the stomata close. When the concentration of the carbon dioxide is lower inside the leaf, the stomata open. It has also been found that stomata open during the day and close at night.

   → Based on this information what hypothesis can you make about the relationship between the opening and closing of stomata and photosynthesis?

   →Explain why you chose this hypothesis.
6. Use arrows to show the relationship between animals and plants and photosynthesis and respiration. Show how carbon dioxide and oxygen cycle between them.

7. Jan Van Helmont did a classic experiment with soil and plants. Read his observations, then answer the questions that follow:

   I put 200 pounds of dried earth in a plant pot. I moistened the pot with rain water. Next I planted a stem of a willow tree that weighed 5 pounds. When the experiment was complete the plant weighed 169 pounds and 3 ounces.

   The plant was watered regularly for 4 falls. I weighed only the tree with out the leaves that fell every autumn. At the end of 4 years I dried the earth in the pot and the earth weighed 200 pounds minus 2 ounces. Therefore 164 pounds of wood and bark arose out of water only.

   a. What was Van Helmont's hypothesis?
   b. How much weight did the willow gain?
   c. How did Van Helmont explain the weight gain?

    d. What would he have found if he included the leaves?
    e. According to these results plants do not eat soil? What do they eat?
    f. What kind of control would you suggest to find out if new plant tissue grows from water alone?
    g. How do we explain the weight increase in the plant today?

8. Respiration in plants:
    a. Look at the following set up:

    →What will happen to the color of the BTB if we put these beakers in the dark? Explain why.

    →What will happen to the color of the BTB if we put these beakers in the light? Explain why.

    b. Read the following lab set up and results. Then answer the questions:
    These two test tubes had BTB and water in both. One test tube had a small week old bean plant. They were placed in the light over night:

Results:

Time	Plant and BTB	BTB only
30 minutes	Green	Blue
1 hour	Yellow	Blue
24 hours	Clear	Blue

→According to these results did the bean plant do respiration? Explain.

→This set up was in the light. Why were we detecting the products of respiration and not photosynthesis?

APPENDIX C-8

BOTANY FINAL: Fall Semester 99/00

Please write on a **separate sheet of paper** to allow for unlimited writing for each answer. Use **complete sentences** for all written responses. Also, remember to **label all diagrams**!!

1. (3 points)Give three reasons why plants need water.

2. (18 points) Describe how each of the following situations would change the water movement (**increase** the amount of water moved or **decrease** the amount of water moved) in plants. Then explain why you chose either increase or decrease. Show me you understand the **properties of water** and how they are affected by a **plant's structure** and a **plant's environment**:
   a. Lots of Wind.
   b. A leaf eating weevil covers half of the leaves with a thick vaseline like slime on the underside of the leaves.
   c. The xylem cells in the stem of an oak are dying because of a tree fungus.
   d. A hot sunny day.
   e. Roots are being eaten by a beetle larvae so that there are no longer any root hairs.
   f. The plant is fertilized to the point where the concentration of water is higher inside the root cells than it is in the soil.

3. (6 points) Make a chart that shows three different types of plant tissues, their functions, and where you would find them on a plant.

4. (2 points) Give an example of a plant that does not have tissues. Explain why that plant can survive without tissues.

5. (9 points) Choose one structure in a plant (root, stem or leaf):
   a. Draw how a cross section of that structure might look under the microscope.
   b. Draw and label as many different types of cells (tissues) as you can inside your structure.
   c. Label your drawing with all of the materials that move in/out your structure. Show which direction they move with arrows.

6. (12 points)You have a device that tells you if the stomata on a plant are open or closed. What would you predict about the stomata in the following situations? Explain why in each case.

a. The concentration of carbon dioxide is low inside the leaf.
c. The concentration of water is l
d. ow outside the leaf (in other words the air is very dry).
c. It is the day and the sun is shining.
d. It is night time!

7. (4 points) Write the equation for photosynthesis in words and chemical formulas.

8. (10 points)Plant fertilizer:
   A. Why is it impossible for plants to take protein and other food molecules in through their roots? (2 points)
   B. What do people consume that is comparable to fertilizer? (2 points)
   C. Describe how Van Helmont investigated the problem: ADo plants get food from the soil?≅ Be sure to include how he tested the problem and what the results were. (6 points).

9. (20 points) Design an experiment that could test if plants actually **use light to convert carbon dioxide from the air into glucose**. One tool you may want to use is radioactive carbon. Assume you have some radioactive carbon that allows you to see where carbon is at any time. Show all parts of the experiment (Problem, Gathering Information...).

10. (20 points)Show ALL OF THE WAYS carbon dioxide and oxygen cycle between plants and animals using drawings or words and arrows. Be sure to include carbon dioxide, oxygen, plants, animals, respiration and photosynthesis in your cycle.

11. (12 points) Draw the life cycle of any seed plant.
   a. Show at least 4 different stages (maybe Day one, Day 10, Day 20, Day 50).
   b. Make sure the life cycle goes from seed to seed.
   c. Label each stage with mitosis and/or meiosis. Show when both processes occur in the life cycle.
   d. Show where the new seeds are formed.

12. (8 points)What is one purpose of each of the following plant parts:
   a. Roots
   b. Stems
   c. Leaves
   d. Flower

13. (8 points) Make a chart that compares mitosis and meiosis in plants. Be sure to demonstrate at least 2 similarities and two differences.

14. (4 points)Genetic Crosses:

a. Tall is the dominant gene for the height of the fast plants. What did we expect to find when we crossed two heterozygous Tall fast plants?
b. Describe how punnet squares represent what could happen in meiosis.

15. (30 points)Draw a concept map that shows connections between the things we studied in Botany and purple loosestrife. Try to make as many connections as you can to accurately represent what you learned this semester:

For each of the following plant drawings:

A. Use arrows to show all of the ways that the different materials move through out a plant.
B. Label each arrow with a brief explanation of what is happening to that material at that point.

I. Make arrows and labels that represent and explain Oxygen movement.

II. Make arrows and labels that represent and explain water movement.

APPENDIX D

Consent Form

PARENTAL/STUDENT CONSENT FORM

TO: The parents/guardians of
FROM: Ms. Weise (Biology teacher)
RE: Requesting permission to use student's work in a Master's thesis paper.

For the past three years I have been spending my summers working on a Master's of Science degree which focuses on modifying the Botany course so it will be more applicable to every day occurrences.

To have a sound thesis I need to collect data on the amount of knowledge gained by each student during a unit about Purple Loosestrife. This unit will last about four weeks. The data needs to come from the students who will be participating in the course for this semester. The purpose of this letter is to seek your permission to use your student's confidential scores and responses in my study. Your student's pretest and posttest scores, journals, and labs will be statistically analyzed to indicate whether or not the unit was effective. Also, some journal responses may be quoted. I assure you that in the thesis your student's name will in to way be associated with any of his/her scores or written responses. The data collection process will be virtually unnoticeable and will not effect your students in any way. Your student's privacy will be protected to the extent of the law possible.

I would encourage you to discuss this with your student as it involves them directly. I have discussed this with the students already and they can probably answer most of your questions. If you have any further questions I can be reached at the high school at 694-2162. A withdrawal in no way exempts the student from doing the same work as everyone else, it just means that I will be unable to use his/her data. You may also contact Dr. Wright if you have any questions regarding human subject issues at (517) 355-2180.

Thank you for your time and I hope to see you at parent-teacher conferences. If you ever have concerns about your student, please contact me, for we are a team in your child's education.

Sincerely,
Ms. Weise
Holt High School
Biology Teacher

_______I give Ms. Weise my permission to use my data collected from the purple loosestrife unit. I understand that Ms. Weise will not use my name and that all my student data will remain confidential.

______________________	________
Printed Student Name	Date
______________________	________
Student Signature	Date
______________________	________
Parent or Guardian Signature	Date

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