Using Plants for Student Research Projects

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Description

Students will work in research teams to do original research (science inquiry) with bean or sunflower plants. They will pose a question about plant growth and development and then write a hypothesis, design an experiment, collect, organize and analyze data, write a conclusion and persuade their peers in a scientific convention.

Grade Range

9 – 10 Introductory Biology

Teaching/Learning Objective(s)

Students will:

- Pose a scientific question about plant growth and development (C.12.1, C.12.2)
- Compose a hypothesis to answer a question on plant growth and development (C.12.1, C.12.2)
- Design a controlled experiment on plant growth and development including an independent variable, dependent variable, control, constants and repeated trials (C.12.1, C.12.2)
- Write specific instructions for an experimental protocol
- Collect and organize data (C.12.4)
- Create graphs from the data collected (C.8.7)
- Analyze data from the experiment (C.12.3)
- Write conclusions to a scientific experiment (C.12.5)
- Communicate experimental conclusions to their peers (C.12.6)
- Critique experimental designs (C.12.1, C.12.2)
- Critique conclusions from scientific experiments (A12.6, A.12.7, C.12.6)
- Describe changes in plants as they grow and develop (F.12.8)
- Describe changes in plants when grown in varying environmental conditions (F.12.8)
- Link results to applications in the world (B.12.4)
- Critique evidence from research done by other students (A.12.7)

Time Required

18 (50 minute) class periods

- Five periods to design and set up the experiment
- One period a week for eight weeks to collect data
- Five periods to analyze data and for scientific convention

Materials and Preparation Procedures

- Containers to grow plants (Styrofoam cups, plastic, peat pots, etc.)
- Water source
- Soil
- Bean seeds (dried beans from the supermarket work well)
- Sunflower seeds (bird seed sunflowers work well)
- Flats to hold the pots
- Handouts as described in the Additional Materials section
    - Plant Project Experimental Design Diagram
    - Plant Project Peer Review Form
    - Plant Project Rubric
- Other materials as needed for student designed experiments

Activity

Science curricula should engage students in science as a problem solving activity. They will then see that science consists of a search for explanations, a process of inquiry that results in generating ideas and constructing knowledge. Students need practice in being scientists if they are to learn "science in the making" and not just "final form science."

As a prerequisite for this activity students need to understand how to pose a scientific question, write a hypothesis, identify an independent variable, a dependent variable, constants, control, repeated trials, make data tables and draw graphs. Three books that are especially helpful in teaching these concepts are listed below in the "Additional Resources" section. You can buy these books online at the National Science Teachers Association Science Store at http://www.nsta.org.

I transform my classroom into MESMERC (Mesmer's Scientific Magnificently Exciting Research Company, Inc.), a scientific research company. Students are divided into research teams of three students to do their research for their "employer." They pick a "team leader" who coordinates all the research efforts for their project.

I tell students that a new variety of bean seeds (purchased in the dried bean section of any supermarket) and a new variety of sunflower seeds (bird seed works well) have been found. Their task is to find the best conditions for growth of these new varieties so the growth conditions can be printed on the packet when marketed. An alternative is to do these experiments with Fast Plants (rapid cycling *Brassica rapa*). Information on this type of plant can be found at http://www.fastplants.org. Fast Plants are a fast growing, widely used plant ideal for the classroom. Advantages of Fast Plants include their short life cycle (one month) and their ability to be grown in a small space.

Students practice asking testable scientific questions about plant growth and development. They need to think of ten to fifteen questions about plants, have their group pick one of these problems to solve and write up a research proposal in the form of an experimental design for an experiment on plants. The Plant Project Experimental Design Diagram gives students a structured way to design controlled experiments that can be used in many experiments. A template follows: (See also Plant Project Research Experimental Design Handout)

Title:

Hypothesis:

Materials:

Independent Variable:

Levels of the
Independent Variable

Repeated Trials

Dependent Variable:

Constants:

I have students write a title that includes the independent variable and the dependent variable, usually as an if/then statement. The hypothesis has to be logical and the materials list complete. The area to the right of the "Levels of the Independent Variable" and "Repeated Trials" can be divided into as many sections as the students have levels of the independent variable. For example, they could be seeing what soil should be used to grow the tallest bean plants. They could choose peat, vermiculite, and potting soil. The area above would be divided into three sections, one for peat, one for vermiculite and one for potting soil. Students must have a minimum of three levels of the independent variable. I usually have students do 5-20 repeated trials for each level of the independent variable depending on the amount of space and materials available. Students need to identify at least three constants. An example of a completed experimental design diagram for plants is as follows:

Title: The Effect of Water Temperature on the Height of Bean Plants

Hypothesis: If the temperature of water is increased, then the plants will grow shorter.

Materials: Navy bean seeds, potting soil, plastic containers to plant plants, flat to hold plants, water

Independent Variable: Temperature of Water

Levels of the Independent Variable	Boiling	Hot	Warm	Cold

Repeated Trials	5	5	5	5

Dependent Variable: Height of plants in cm.

Constants: Type of soil, type of seed, type of container, amount of light, amount of water

I used to have students do this problem individually at home since we did not have room to complete the project at school. We now have a greenhouse and we are fortunate enough to be able to complete our experiments there, making the five-minute walk to the greenhouse once a week for 6-8 weeks to water plants and take data. I keep the students' data tables in folders at the greenhouse so that data are not lost. I also keep graduated cylinders and rulers at the greenhouse for measuring plant height and amount of water. As mentioned above, an alternative is to use Fast Plants, rapid cycling *Brassica rapa*, which can be grown quickly in a small area.

We then practice writing directions for the experimental procedure. Students often have trouble being specific enough so that someone else can follow their directions. As an activity that they will enjoy, as well as one that will help them realize the importance of detailed directions, I have students write down the directions for making a peanut butter and jelly sandwich. I ask for volunteers to read their directions, and I try to follow them literally. For example, if they omit the step of taking a knife in hand and only say "get some peanut butter and spread it on the bread," I may dip my finger into a jar (reserved especially for me for this instance!) and start spreading peanut butter on the crust with my finger. I then have students read their instructions to another person and have them follow the directions exactly. The reader can revise their instructions as they realize the ambiguities in their writing. It is a rare student that writes complete instructions on the first try, but when asked to revise again and again, everyone eventually writes detailed descriptions and is able to make (and eat) a peanut butter and jelly sandwich. Students then write out detailed procedures for their experiments.

At each stage of the experiment, students submit their ideas to a "colleague" (another team) to critique their design and offer suggestions on how to improve it. Students may use the Plant Project Peer Review Form. We talk about how professional scientists write research proposals and submit them for grants. Student teams then submit their own research proposals to the CEO of the research corporation (the teacher) for funding. In this instance everyone gets funded when his/her proposal is acceptable.

Next, students make data tables for their experiments. Students do not often realize that scientists have to keep detailed, accurate and organized information from their experiments. There is usually not one "right" way to keep track of data, so I have them choose what they consider the best way from a variety of methods. You may want to advise students of the most usable format to be used with the spreadsheet program that you plan to use to graph the results. Each data table needs to have a title including the independent variable, the dependent variable, the date the data is taken, units of measurement, and any criteria outlined.

Many times there will be problems with the experiments. The seeds may not germinate or mold may kill the plants. Students begin to realize that science experiments do not always happen as expected and that professional scientists get frustrated. Often, they learn more from their "failures" than their successes. These serendipitous happenings are common in science.

I usually have students take data for 6-8 weeks. Students work in their groups to draw graphs to represent their data. The graphs need to include an appropriate title, axes and key labeled, an appropriate scale, the points plotted correctly, and the curve accurate. We talk about how to analyze data to form a conclusion to an experiment. I emphasize that different methods of collecting data on the same experiment might yield completely opposite results. We try to find examples with the students' experiments. One common example is the answer to the question of whether plants grow "better" in the dark or light. Students are amazed that those growing in the dark are often taller than those in the light for the first few weeks, although the health of the plants is markedly worse since they are yellow, weak and often do not have leaves. If students were measuring only the height of the plants they would come to the conclusion that plants grow "best" in the dark. If they were to measure the health of the plants using a qualitative scale with defined criteria, they would come to the opposite conclusion.

We discuss what should be included in the conclusion of the experiment, including the purpose of the experiment, the major findings, whether the hypothesis was supported by the data, the explanation for the findings, how their findings compare with other researchers, how their results apply to the "real" world and recommendations for improving the experiment. When the experiments are completed, the research teams have three class periods to assemble all of their information into final form for a three day "Scientific Convention" complete with an agenda, banners, and nametags with "Dr." and the student's last name. The final project can be written by hand largely on several pieces of poster board or presented as a power point presentation on a large screen monitor or with a computer projector. The objective is for everyone in the class to be able to read everything that the group presents. Each team has five to ten minutes to present its experimental design, procedure, data table, graph and conclusion. The other "scientists" in the audience then critique the experiment. This activity illustrates the importance of peer review to the scientific community and how all knowledge that is generated needs to be brought before peers for criticism. A Plant Project Rubric for assessing the final project is included.

If students are taught to design experiments using minimal equipment and cost, I have found that they will do experiments at home to find explanations for the questions that they ask about the natural world. Students learn that they do not always have to reach for a book or ask an authority for an answer. It becomes more fun and rewarding to discover the answer for themselves. The sense of satisfaction found in this type of explorative learning cannot be matched by just being told the answer. In offering students this model of a scientific community I feel that everyone can be a winner and get "paid" with a good grade, success with peers, the satisfaction of a job well done, and an understanding of how science operates. Not many of my students will choose science as a career, but they can continue to be scientists in a small way for the rest of their lives.

Student Assessment

Students will use the Plant Project Peer Review Form to assess their peers on their research proposal.

Students will be assessed on the final presentation at the scientific convention through the use of a detailed Plant Project Rubric.

Wisconsin Science Standards

A. Science Connections: Students will understand that there are unifying themes: systems, order, organization, and interactions; evidence, models, and explanations; consistency, change, and measurement; evolution, equilibrium, and energy; and form and function among scientific disciplines. Those themes are to be used to connect the science content standards for Wisconsin to each other.
A.12.6 Replace inaccurate personal models using evidence
A.12.7 Re-examining evidence

B. Nature of Science: Students will understand that science is ongoing and inventive, and that scientific understandings have changed over time as new evidence is found.
B.12.4 Basic and applied research contributing to new discoveries and applications

C. Science Inquiry: Students will investigate questions using scientific methods and tools, revise their personal understanding to accommodate knowledge and communicate these understandings to others.
C.8.7 Explain data to peers
C.12.1 Design investigations
C.12.2 Write questions, design and conduct investigations
C.12.3 Evaluate and critique data
C.12.4 Collect data
C 12.5 Develop explanations
C.12.6 Present results of investigations

F. Life and Environmental Science: Students will demonstrate an understanding of the characteristics and structures of living things, the processes of life, and how living things interact with each other and their environment.
F.12.8 Changes in environmental conditions

Additional Resources

For teaching experimental design found at www.nsta.org:

- *Science Experiments and Projects for Students* by Julia Cothron, Ronald N. Giese and Richard Rezba
- *Students and Research* by Julia Cothron, Ronald N. Giese and Richard Rezba
- *Science Experiments by the Hundreds* by Julia Cothron, Ronald N. Giese and Richard Rezba

Plant Resources:

- http://www.growlab.com offers suggestions on inquiry science with plants for grades K-8.
- http://www.fastplants.org focuses on Fastplants (rapid cycling *Brassica rapa*.)

Additional Materials

- Peer Review of plant project experimental design
- Plant Project Research Proposal form
- Rubric for Plant Research Project