Plant Content in the National Science Education Standards

David R. Hershey

An ActionBioscience.org original article

articlehighlights

The National Science Education Standards (NSES) provides few resources for teaching about plants. To assure students understand and appreciate plants:

- *don't neglect plants in teaching basic biological concepts*
- *avoid animal chauvinism in biology coursework*
- *correct pseudoscience and anthropomorphisms about plants*
- *make plant studies fascinating and relevant*

The National Science Education Standards (NSES) provide a framework for teaching precollege science.[28] However, it does not stress the fundamental importance of plants in science teaching.

The NRC recommends teaching botany at every grade level.

- A 1992 National Research Council (NRC) report emphasized that "our knowledge about the world around us is incomplete if we do not include plants in our discoveries, and it is distorted if we do not place sufficient emphasis on plant life."[27]

The NSES does not address

- A 1990 NRC report urged that, "because plants are especially easy to grow and care for, students at every grade level should be involved with gardening projects…. Both domesticated and native plants should be grown and observed. The ecological and

aspects of teaching about plants.

agricultural importance of plants should be a major point of emphasis. The historical importance of agriculture in the development of the human race provides an ideal opportunity to integrate the social and natural sciences."[26]

The NSES does not have such strong statements about the importance of plants in science teaching nor does it even contain the words agriculture and gardening. It also does not address challenges unique to plant teaching. If students are to become knowledgeable about plants, teachers need to be aware of the following five challenges.

Don't neglect plants

Introductory biology courses often neglect plants.

There is "a recognized tendency, even for knowledgeable biologists, to overlook, underemphasize or neglect plants when teaching introductory biology courses."[35] Too often, biology is "botany taught by a zoologist," leaving students with "the popular delusion that biology is the study of animals."[29] This results in widespread ignorance about and underappreciation of plants.[3,4,10,14,33,36]

This underappreciation of plants is apparent in the NSES. For example, they include the statement, "All animals depend on plants. Some animals eat plants for food." (p. 129) That greatly understates the importance of plants to civilization.

- Plants also provide oxygen and shelter for animals, including humans.

Teaching about plants provides essential biological information.

- People depend on plants for energy, medicines, rubber, cotton, wood, paper, cardboard, inks, oils, soaps, perfumes, gums, resins, turpentine, pesticides, poisons, dyes, toys, and thousands of other products.[20] An amazing statistic of our dependence on plants is that each gallon of gasoline is derived from 198,000 pounds of ancient plant matter.[8]

- Environmental benefits of landscape plants include shade, cooling, noise abatement, screening of unsightly views, erosion prevention, and windbreaks.[30]

- Plants provide inspiration for art, architecture, humor, poetry, and literature, as well as beauty, holiday decorations, tourist attractions, jobs, and hobbies such as gardening. They are also important in religion, as state trees, as state flowers, and on stamps, currency, coins, and flags.

- Ancient trees are revered for their longevity, size, and connections to famous people, places, and events.[21,24]

Given the widespread ignorance of plants and plant neglect in biology classes, teachers need to make a special effort to assure that both they and their students learn about plants.

- Ask students the bumper sticker question “Have You Thanked a Green Plant Today?” Have interesting suggestions ready to add to student replies, such as a “Zillion Uses for Corn,” cocklebur inspiring the invention of Velcro, use of osage orange as living barbed wire, use of chia (of ChiaPet fame) by Aztecs, and plant medicines such as quinine, aspirin, taxol, morphine, reserpine, digitalis, and vincristine.[20]

- Grow odd and fascinating plants in the classroom, such as carnivorous plants, sensitive plant, piggyback plant, resurrection plant, redwood burl, sea onion, prayer plant, and papyrus.

- Use supermarket botany in one of the following ways:

    - Assign each student a different aisle in the supermarket and see how many plant species they can find represented there.
    - Have students identify what plant part—root, stem, leaf, flower, fruit or seed—they are eating for produce and processed foods.
    - Grow plants from supermarket produce, such as ginger, carrot, potato, sweet potato and pineapple, date, star fruit, avocado, mango, pomegranate, papaya, citrus, peanut, and coffee.

Plant activities ignite the imagination and ensure learning of basic biology.

- Include plants in other disciplines such as chemistry, history,[11]

and space science:

- Prepare hydroponic solutions to produce mineral nutrient-deficient plants and let students use semiquantitative chemical analysis to determine which mineral nutrient is missing.
- Study how plants cause pH shifts in hydroponic solutions.
- Study the chemistry of acid rain and its detrimental effects on plants.
- Examine the historical impact of crops such as potato, tea, cotton, corn, peanut, sugar cane, quinine, opium, tulip, and coca.
- Simulate plant growth in space or in a Mars colony.

Avoid animal chauvinism

Zoochauvinism is a bias for animals and against plants.

Animal chauvinism, or zoochauvinism, is a bias against plants in favor of animals.[6,17] It seems to afflict many biology teachers. A columnist for the *American Biology Teacher*, the leading journal for biology teachers, stated the bias this way: "We are all more interested in animals."[9] Of course that is not true. It is ironic that the two most prominent biologists in most biology texts were strongly interested in plants. Gregor Mendel studied inheritance in pea plants, and Charles Darwin wrote several books on plants. Prejudices against plants are illogical because if all plants became extinct, most of the human population would starve. We would survive quite nicely if all other animal species became extinct.

Textbooks devote more chapters to animals than plants.

Leading high school textbooks devote just 14% of their chapters to plants, compared with 42% to animals and humans.[34] Surveys indicate students prefer to study animals rather than plants.[35,36] However, some of that may reflect the animal chauvinism of their teachers or society, or that many teachers don't know enough about plants to teach botany well. As a teacher, be sure you are not biased against plants and devote sufficient time to plants. Teach students that plants are not only vital to human survival but are also fascinating organisms. Here are some suggestions:

- Enhance the plant in a jar exercise (NSES pp. 92-97) with the intriguing stories of the accidental invention of the terrarium and of humans sealed inside Biosphere II, a giant terrarium in the Arizona desert.

- Enrich the history of photosynthesis lecture (NSES pp. 194-196) by having students use the simple techniques of photosynthesis researchers in the 1600s and 1700s. For example, in 1699, John Woodward compared growth and water use of mint plants grown in glasses of water with various amounts of dissolved or suspended solids.[18] Also use simple techniques that help students visualize photosynthesis.

- The Science and Technology project for grades 5-8 (NSES pp. 161-164) could easily involve plants rather than an egg drop. Students could construct a hydroponic system from recycled and readily available materials and use it for plant experiments. Hydroponics experimentation should be an essential part of science teaching because it clearly disproves the widespread misconception that plants "eat" soil. The hydroponics display at Walt Disney World's Epcot Center is its most popular exhibit, and students are usually fascinated by hydroponics.[25]

Teachers must supplement coursework with plant activities.

- Emphasize dramatic plant concepts; for example, plants are the dominant organisms on land on a mass basis, and photosynthetic plants get most of their dry mass from a trace gas in the atmosphere. Plant dry matter is literally constructed out of thin air!

- Have students compare and contrast animals and plants. In particular, compare human systems for mechanical support, "digestion, respiration, reproduction, circulation, excretion, movement, control, and coordination, and for protection" (NSES p. 156) with analogous plant systems. Most biology texts have chapters devoted to each human system but exclude plants from those chapters. Teachers should pick textbooks that discuss these basic biological functions, such as gas exchange, for all organisms together—animals, plants, fungi, and so on—rather than in taxonomically oriented chapters (i.e., chapters on gas exchange in animals, gas exchange in plants, etc.).

- Connect human nutrition to plant function by asking students why plants are rich sources of fiber, vitamin A, and vitamin C.

- Make plant teaching relevant to increase student interest.[13] Traditionally, plant content in biology texts is basic, rather than applied yet science "Content is fundamental if it applies to situations and contexts common to everyday experiences." (NSES p. 109). Here are examples: [15]

    - Application of apical dominance in pruning trees and shrubs.
    - Use of plant hormones in agriculture, such as gibberellins to increase size of seedless grapes and ethylene to induce flowering in pineapple and ripen tomatoes.
    - Application of differences in stem anatomy between monocots and dicots in grafting.

Don't let science standards discourage plant use

State science standards often do not use plants as examples of basic biological concepts and sometimes exclude using plants in some situations.[34] Plants provide excellent examples and experimental subjects for all the life science standards (NSES p. 106), yet the NSES sometimes excludes them:

- Pages 124-125 describe keeping a pet hamster in the classroom and using it in a study on evaporation from a watering can. However, a plant would make an excellent "pet" as well and would work better in an evaporation study given that plants evaporate large amounts of water.[2] Measuring transpiration also was important in the history of photosynthesis research, unlike the contrived NSES scenario that the hamster escapes from its cage at night to drink water from the watering can. The more fundamental question is why plants have to be watered so frequently with the watering can.

- Pages 128-129 talks about "behaviors that help various animals survive." There was no logical reason to limit the concept to

NSES also

preference for animals in its recommendations.

animals when it also applies to plants. The six-part BBC television series, "The Private Life of Plants," is an excellent source for behaviors that help plants survive.[1]

- Page 187 states, "The broad patterns of behavior exhibited by animals have evolved to ensure reproductive success. Animals often live in unpredictable environments, and so their behavior must be flexible enough to deal with uncertainty and change. Plants also respond to stimuli." Plants should not just be mentioned as an afterthought. Plants also have "broad patterns of behavior…[that] have evolved to ensure reproductive success," especially coevolution with animals that distribute a plant's pollen and seeds.[2][3] Plants have a greater problem with "unpredictable environments" because they cannot seek shelter as many animals can.

Plants offer many advantages for class experiments and demonstrations.

Teachers should not let science education standards prevent use of plants in the classroom. Plants offer many advantages for class experiments and demonstrations. They are inexpensive, readily available, easy to work with, and avoid ethical problems that may arise with animal experiments and dissections. The potential dangers and disposal problems of microbe cultures are also avoided. There are many inexpensive plants that do well under classroom conditions. Common houseplants, especially devil's backbone and amaryllis, are excellent. There are two marvelous model plants for teaching, Fast Plants and C-Fern. Plant growth experiments also satisfy the recommendation (NSES p. 113) for more emphasis on "investigations over extended periods of time."

Don't be fooled by authors "practicing botany without a license"

There are hundreds of errors or misconceptions about plants in

Many science teaching materials contain misconceptions about plants because the authors have insufficient plant training. For example, a Smithsonian Institution website states that "hardworking bees pollinated the potato plant that eventually became potato chips and French fries."[31] That is misleading because no pollination is required given that the edible potato tuber, an underground stem, is not a flower, fruit, or seed. Most cultivated potatoes are asexually propagated.

literature.

There are hundreds of errors or misconceptions about plants in the teaching literature, so teachers need to be on guard for them.[19] Even refereed biology teaching journals occasionally publish very inaccurate plant articles. Four letters to the editor of *American Biology Teacher* pointed out numerous errors in one botany teaching article penned by zoologists.[7]

Plant misconceptions in the NSES include these:

- "Plants and some microorganisms are producers." (p. 157) That is misleading because over 300 parasitic plant species are consumers and lack chlorophyll, among them the fabulous *Rafflesia arnoldii* with the world's largest flower.[1,16]

The NSES exhibits some of the plant misconceptions.

- "Plants also reproduce sexually—the egg and sperm are produced in the flowers of flowering plants…. That new individual receives genetic information from its mother (via the egg) and its father (via the sperm)." (p. 157) That is misleading because a self-pollinating plant acts as both parents, contributing both egg and sperm.

- "Sexually produced offspring never are identical to either of their parents." (p. 157). Although uncommon, a single homozygous parent can produce sexual offspring that are genetically identical to it. That is the basis of self-pollinated crops that come true from seed, such as the pea cultivars Mendel started with in his experiments, plus crops such as tomato, soybean, rice, and wheat. Such crops produce offspring that are very nearly identical to their self-pollinated parents.

- "Only mutations in germ cells can create the variation that changes an organism's offspring." (p. 185) That is not exactly true in plants that reproduce asexually or are asexually propagated. Plant cloning is very important in many wild species and especially in agriculture.[5] Mutations in vegetative cells have been responsible for thousands of new cultivars. Examples include many plants with variegated leaves due to chimeras and hundreds of apple cultivars that arose from bud sports such as Red Fuji, a sport of Fuji, and Royal Gala, a sport of Gala.[22]

Science teachers should be wary of plant teaching materials written by nonbotanists. Plant project books written by nonbotanists often contain numerous misconceptions, so teachers may wish to screen them before recommending them to students. Teachers with questions about potential plant misconceptions should query madsci.org or the bionet.plants.education newsgroup.

Deal with plant pseudoscience and anthropomorphisms

Teachers should guide students to avoid pseudo-science projects.

Plant pseudoscience includes widespread beliefs that plants grow better when sown during certain phases of the moon, that plants have ESP, and that plants grow better when people talk to them, say prayers for them, or play certain types of music. Certain products for plant growth are also pseudoscientific, such as many exotic plant fertilizers and biostimulants. Metal probe meters to measure soil pH, fertility, and water content are ineffective yet are sold by science education suppliers.[12] Whether music affects plant growth is a very popular student science project, but precollege students lack the equipment and facilities to properly perform such experiments. Teachers should guide students to avoid pseudoscience projects. There are plenty of valid student projects with plants.

The NSES notes that anthropo-morphism is common in young students.

Several types of plant pseudoscience are anthropomorphic, such as supposed beneficial effects of music, talking, and human medicines on plant growth. The NSES notes that anthropomorphism is common in young students, but they outgrow it as they gain knowledge. With widespread plant neglect, anthropomorphism with plants seems to persist longer. One of the most common questions at madsci.org comes from middle or high school students who irrigate plants with human beverages, such as coffee, tea, milk, and soda. Students are at a loss to explain their results because biology textbooks and the botany literature don't discuss the topic. Teachers should guide students away from anthropomorphic plant projects by reminding them of the requirements for photosynthesis. Rather than irrigating plants with human beverages, students could irrigate plants with different types or concentrations of fertilizer solution.

Conclusion

Don't let science standards discourage plant use in the classroom.

"Plants are the most important, least understood, and most taken for granted of all living things."[36] To ensure that students understand and appreciate plants, don't neglect plants in teaching. Avoid animal chauvinism by making plant studies fascinating and relevant. Don't let science standards discourage plant use in the classroom. Don't be fooled by authors practicing botany without a license. Effectively deal with student beliefs in plant pseudoscience and anthropomorphisms. Classroom ideas for teaching about plants are provided in the Get Involved Links below in the section "classroom reading, activities, and other resources."

David R. Hershey, Ph.D., is a biology education consultant and author of *Plant Biology Science Projects* (1995, Wiley). He has published over three dozen teaching articles in journals such as *Science Teacher*, *Science Activities*, *Plant Science Bulletin*, *American Biology Teacher*, and *BioScience*. He answers botany questions for madsci.org and often contributes to the bionet.plants.education newsgroup. Hershey received his Ph.D. in plant physiology from University of California at Davis.
http://www.fortunecity.com/greenfield/clearstreets/84/bio.htm

learnmore links

National Science Education Standards
Read this searchable framework for U.S. precollege science education.
http://www.nap.edu/books/0309053269/html/index.html

Twelve Principles of Plant Biology
Learn what the American Society of Plant Biologists consider to be the top 12 fundamental concepts about plants.
http://www.aspb.org/education/foundation/principles.cfm

Ethnobotanical Leaflets
Examine hundreds of fascinating plants and the remarkable ways people use them.
http://www.siu.edu/~ebl

Invasive Plants
Learn how thousands of invasive foreign plants are damaging native ecosystems and what you can do about it.
http://www.nps.gov/plants/alien

Parasitic Plant Connection
Discover the fascinating world of parasitic plants in this site by Dan Nickrent, of the Department of Plant Biology at Southern Illinois University, Carbondale.
http://www.science.siu.edu/parasitic-plants

Wayne's Word Plants
Explore dozens of fascinating and well-illustrated webpages on plants by Professor Wayne P. Armstrong, of Palomar College.
http://waynesword.palomar.edu/worthypl.htm

Axel Erlandson's Tree Circus
Discover how grafting was used to create living plant art.
http://www.arborsmith.com/treecircus.html

Angiosperm Pollination Syndromes
Explore how flowering plants pay or fool animals into carrying pollen for them.
http://www.cas.vanderbilt.edu/bioimages/pages/pollination.htm

Epiphytes—The High Life
Discover the 10% of seed plant species that live high in the trees.
http://www.rbgkew.org.uk/ksheets/epiphytes.html

Seagrasses: Flowering Plants That Live in Sea Water
Learn about this overlooked and ecologically important group of plants that live submerged in the oceans.
http://www.aims.gov.au/pages/research/project-net/seagrass/apnet-seagrasses01.html
http://www.dep.state.fl.us/coastal/habitats/seagrass/

getinvolved links

Botanical Society of America
K-12 education pages include carnivorous plants, “Sailing Seeds: An Experiment in Wind Dispersal,” “One Bad Apple: Synchrony in Ripening Fruit,” and a list of “Web Sites for Young Botantists.”
http://www.botany.org/newsite/education/

American Society of Plant Biologists
K-12 education features include a curriculum simulating plant growth on the moon, “How many plants it takes to make a Big Mac®?” and “What in your house was made from plants?”
http://www.aspb.org/education/NEWK12.CFM

American Phytopathological Society
K-12 education features include “The Christmas Tree: Traditions, Production, and Diseases” and an illustrated glossary of plant disease terms.
http://www.apsnet.org/education/K-12PlantPathways/Top.html

Classroom reading, activities, and other resources
1) Reading - online

- » American Forests Historic Trees: http://www.historictrees.org
- » Armstrong, W.P. 1988. The Remarkable Cocklebur: Worldwide Hitchhiker & Nature’s Velcro®: http://waynesword.palomar.edu/plapr98.htm
- » Hershey, D.R. 1996. Doctor Ward’s accidental terrarium. *American Biology Teacher* 58: 276-281. http://www.angelfire.com/ab6/hershey/ward.pdf
- » Hugo, N.R. 2003. The mystery of Patrick Henry’s osage-orange: Which enigma is greater; the age of the national champion or how it got to Virginia? *American Forests*
  http://www.findarticles.com/p/articles/mi_m1016/is_2_109/ai_106141724
- » Massive Misunderstanding Mess at Mars:
  http://www.the-solar-system.net/webquests/mars-webquest.html
- » David, L. 2000. Biosphere 2: Science Under Glass.
  http://www.space.com/scienceastronomy/generalscience/biosphere2_001110.html
- » Zillion Uses for Corn: http://www.ontariocorn.org/classroom/products.html
- » Mendel, G. 1865. Experiments in Plant Hybridization.
  http://www.mendelweb.org/Mendel.html

2) Activities

» Edward Lear's Nonsense Botany: http://www.nonsenselit.org/Lear/ns/nb.html
» C-Fern: http://cfern.bio.utk.edu/
» Exploring Photosynthesis with Fast Plants: http://www.fastplants.org/pdf/activities/exploring_photosynthesis.pdf
» Fast Plants: http://www.fastplants.org/
» Hershey, D.R. 1995. Don't just pet your chia. *Science Activities* 32: 8-12. http://www.highbeam.com/library/doc0.asp?DOCID=1G1:17633145&refid=ip_almanac_hf
» Hershey, D.R. 2000. The pleasures and the pitfalls of plant science activities. *Science Activities* 37: 3-5. http://www.highbeam.com/library/doc0.asp?DOCID=1G1:66239828&num=4&ctrlInfo=Round9c%3AProd2%3ASR%3AResult&ao
» Hershey, D.R. 2002. Using the *Kalanchoe daigremontiana* plant to show the effects of photoperiodism on plantlet formation. *Science Activities* 39: 30-34. http://www.highbeam.com/library/doc0.asp?DOCID=1G1:92028435&num=10&ctrlInfo=Round9c% 3AProd2%3ASR%3AResult&ao
» Hershey, D.R. 2002. *Hippeastrum* is hardly a humdrum classroom plant.*Science Activities*39: 19-26. http://www.highbeam.com/library/doc0.asp?DOCID=1G1:95448411&num=16&ctrlInfo=Round9c%3AProd2%3ASR%3AResult&ao
» Smithsonian Center for Education and Museum Studies. Partners in Pollination. http://www.smithsonianeducation.org/educators/lesson_plans/partners_in_pollination/intro_4.html

4) Other Resources

» Attenborough, D. 1995. *The Private Life of Plants*. Princeton, NJ: Princeton University Press. Based on the six-part BBC television series, which is available on video and DVD.
» Williams, P.H. 1997. Teachers and Students Investigating Plants in Space. Washington, DC: NASA. http://virtualastronaut.jsc.nasa.gov/teacherportal/pdfs/InvestigatingPlantsinSpace.pdf
» Hangarter, R. P., and H. Gest. 2004. Pictorial demonstrations of photosynthesis. *Photosynthesis Research* 80: 421-425. http://www.life.uiuc.edu/govindjee/Part3/35_HangarterStarchPics.pdf
» Garden Mosaics web site (information, resources, and activities): http://www.gardenmosaics.cornell.edu/

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