Using globe plant phenology protocols to meet the National Science Education Standards

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The National Education Standards not only insist inquiry is central to science learning but also emphasize the importance of investigations over extended periods of time which use process skills in context (National Research Council, 1996). We all may heartily agree with the emphasis but still be challenged to find sufficient space in our instructional time. One ready solution, however, is to borrow protocols and data from the multi-federally funded Global Learning and Observations to Benefit the Environment (GLOBE) program. There are at least two ways to do this. One way is to become a GLOBE-certified instructor and contribute directly to the GLOBE program. (See the GLOBE web site, www.globe.gov, for listings of teacher-certification workshops near you.) The other way is to adapt the GLOBE protocols for an independent long-term study conducted within just your own classroom.

GLOBE’s newest area of study, plant phenology, is an especially rich resource for long-term classroom studies. Why? It is because GLOBE’s plant phenology protocols require only a minimum investment in materials and time. In return, these protocols can provide the necessary context for students to more fully understand major biogeochemical cycles and begin to look at Earth as a system. Best of all, it can also enable students to gain insight about data collection, analysis, and exploration and help them learn experientially the nature of science.

More About GLOBE ...

Let’s digress for just a moment for those readers who may not have heard about GLOBE. GLOBE (Global Learning and Observation for the Benefit of the Environment) is an international environmental science and education program in which K-12 school-children collect environmental data and “publish” them on the Internet. The four main areas of study are atmosphere, hydrology, land cover/biology, and soil, but plant phenology has recently been added as a new area of investigation.

GLOBE is an exceptionally strong student/scientist partnership program. The sophisticated GLOBE web site (www.globe.gov) enables students to call up visualizations of their data and compare them with other schools’ data, contact other GLOBE students, publish their own studies, and have web-chats with GLOBE scientists. The web site also lists

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Background Information on Plant Phenology

Phenology is the study of living organisms' seasonal activity and the environmental factors driving it. The environmental factors might include variations in day length or duration of sunlight, precipitation, temperature, and other life-controlling factors (Running & Hunt, 1993). For all land creatures such as ourselves, the greening up of plants in the spring and their greening down or senescence in the fall is what makes survival possible. Plant phenology, and more specifically the growing season, has always been critically important to humankind. In ancient times, people worshiped Earth goddesses such as Ceres and Persephone (Bell, 1991; Bonnefoy, 1991) who were in control of the growing season, and astronomers who could keep track of the seasons were trusted advisors to the ruler (Chang, 1986; Keightley, 1983).

Most modern people no longer worship earth goddesses but we still are acutely aware of the growing season and if drought or anything else interferes with it. Plants take up carbon dioxide during photosynthesis and we are becoming more aware of the role of carbon dioxide as one of the "greenhouse gases" that regulates temperature on our planet. Plants also contribute to cloud formation by transpiring water vapor during photosynthesis. Thus, the growing season is important for both the water cycle and the carbon cycle and in current issues of global warming. Figure 1 is a graphical organizer that ties together plant phenology (timing and duration of the growing season) with the water cycle, carbon cycle, and NASA's remote sensing devices aboard satellites. All of these components are critical factors in our developing models of global climate and global climate change (Hughes, 2000; Verbyla et al., 1999).

Plant phenology is currently being studied in many places and in many different ways. While some scientists are studying the great diversity of phenological patterns in the aseasonal tropics (Borchert, 1998; Corlett & LaFrankie, 1998), other scientists are making observations in subarctic and arctic regions (Artt et al., 1999; Junttila & Robberecht, 1993; Phoenix et al., 2001; Thorhallsdottir, 1998). Some phenology studies are done in areas as small as a subalpine meadow or the
central highland of Iceland (Price & Waser, 1998; Thorhallsdottir, 1998), but other studies may cover areas as large as Europe or North America using databases built up over decades from individual data collecting sites or even remote sensing devices on satellites (Chmielewski & Rotzer, 2001; Iverson et al., 1999; Myeni et al., 1997; Royer et al., 1997). Many phenology studies focus on a single species (Olszyk et al., 1998; Juntrilla & Robberecht, 1993) – especially those plants that are a stable human food source such as rice, wheat, and apples (Mahmood, 1997; Oukabi et al., 1998; Serrano et al., 2000) but other studies may encompass multiple species (Chmielewski & Rotzer, 2001; Iverson et al., 1999; Myeni et al., 1997; Royer et al., 1997). Although frequently bud-burst is the datum of choice for plant phenology studies (Chuiine, 2000; Hänninen, 1995; Wielgoslaki, 1999), other factors such as flowering, fruit production, and even seed banks (Onaindia & Amezaga, 2000) are also used. Finally, some of the most interesting recent work combines plant phenology in relation to animal phenology. Examples of this work include a study on the species composition and abundance of birds in relation to fruit and flower abundance in subtropical Argentinian forests (Malizia, 2001) and the amount of leaf beetle damage to a herbaceous perennial plant growing differently in a high altitude site than a low altitude site (Suzuki, 1998). The multiplicity of these studies points to the current emergence of phenology as an important focus for ecological research (Schwarz, 1999).

Overview of GLOBE Phenology Protocols & Materials

Performing the GLOBE phenology protocols is not time-consuming. Once the phenology site is set up, the protocols only require a few minutes a day twice a week for a few weeks. GLOBE has one set of protocols for grasslands and a separate set of protocols for areas with deciduous trees or shrubs. To measure plant phenology with deciduous trees, students simply note when four buds per tree branch (on three or more trees) burst, and measure the emerging leaves until they are fully grown in the spring. In autumn, students record the leaf color as they change and stop collecting data when the four leaves either change fully from green to yellow, orange, red or brown, or leaves fall from the tree(s). For grasslands, students note the emergence of the first four green grass shoots in the spring and measure their growth until the grass stops growing. Students return in the fall to record when the leaves turn color from green to yellow, orange, red, brown, or are completely covered with snow.

The only materials necessary in the spring for both grasslands and deciduous trees are a bit of flagging tape or some other durable identification, a fine tipped permanent marker, SI ruler with millimeter markings, pencil, and paper. For the fall protocols, a GLOBE Plant Color Guide (item #77898 listed for roughly $8 from Forestry Supplies, Inc.) as well as paper and pencil are necessary. A GPS is needed for a one-time use of initially identifying the site.

The following sections briefly describe the GLOBE protocols. For the full details including field guides, teacher support, and FAQs, check the GLOBE web site, http://www.globe.gov. More specifically, the phenology protocols themselves can be found at http://www.globe.gov/fsl/html/templates/measpage phenflang=en&nav=1.

GLOBE Plant Phenology Protocols with Deciduous Trees or Shrubs

Step 1. Site Location

If you are independently setting up the plant phenology project for just your own classroom, you will need a minimum of three trees for interesting comparisons. More trees, of course, mean more data, more emergent patterns, and more scientific questions and hypotheses that can be raised and tested.

When helping your students select their trees, keep in mind GLOBE’s main purpose; i.e., your students are “ground truthing” satellite data on the growing season for your area. You need to identify the trees down to genus and species and check to be sure they are native so that they truly reflect the particular growing season in your area as affected by the local climate. Green-up and green-down cycles for non-native species may not be tied to the local climate. The trees you select should not be near buildings and should not be watered or fertilized since these factors may also interfere with when they put out and drop their leaves. Ideally, the trees you select will also be one of the one to three over-story species that are dominant in your region and have the largest share of canopy cover. Green-up and green-down detected by satellites would be influenced mostly by these few dominant species. Finally, if you are a GLOBE-certified instructor, it is better to choose a GLOBE plant phenology site close to the weather station (GLOBE Atmosphere site) and GLOBE Soil Moisture Study site because the green-up and green-down measurement results may be related to air/soil temperatures, precipitation, and soil moisture data.

GLOBE, however, is interested in all data so simply do the best you can in selecting trees that your students can visit twice weekly or daily during the week(s) you are collecting phenology data. A group of inner-city
schools in Cleveland, Ohio that piloted the green-down protocols, for example, used any native species of tree they could find that was near their schools and had branches that could easily be reached. Fortunately, these trees weren’t pampered with water or fertilizer. They were, however, unavoidably close to buildings and students made sure they reported the closeness to buildings in their site description.

Once you and your students have selected your trees, locate them with a GPS, and take pictures in all four directions, north, south, east, and west. This is now your GLOBE phenology site. Keep in mind that scientists would like at least 10 good solid years of data. By using the same trees (and if at all possible, the same branches) year-after-year, you automatically eliminate a lot of extraneous variables that could interfere with your results. Different species of trees, for example, vary as to when they start and end their active growing season. One further note is that your selected (large) branch should be on the south side of the tree if you’re in the Northern Hemisphere and on the north side of the tree if you live in the Southern Hemisphere. This makes the GLOBE data collection uniform in each hemisphere across all the schools. Lastly, you need a branch that students can observe readily but try to find one that is at the edge of a tree stand (or tree clump), since branches inside a stand may experience a different microclimate due to shading.

Step 2. Green-Up in the Spring

“Bud-burst” refers to the swelling of the leaf bud in the spring when the bud reveals the first glimpse of the green leaf ready to emerge. You need to start observations for the green-up protocol a few weeks before bud-burst normally occurs. Mark the branch on each tree your students are observing with a flagging tape or some other durable identification and include a unique number plus your name/group name, school name, and class. Locate the terminal bud at the end of the branch and label it by marking one dot on the branch next to the bud. Locate three lateral buds closest to the terminal bud and label these buds by marking two, three, or four dots next to them. Now you and your students are ready to observe twice weekly. On the data sheet, record each time your students visit the tree. Record if no swelling has occurred, when it first occurs, and when your students first observe bud burst. (Remember: bud burst occurs when a tiny bit of green is first visible in the swollen bud, indicating that the leaf is starting to emerge.) As the leaf emerges, students can use a metric ruler to measure the leaf blade from its tip to its base. They should not include the leaf stem, alias petiole, in their measurements. When the leaf stops increasing in length (two consecutive observations of the same leaf length), students are finished measuring and it’s time to have fun with the data by graphing the leaf growth and calculating the percent of leaf growth. To graph the leaf growth, plot the leaf length on the y-axis and the dates on the x-axis. To calculate the percent leaf growth, divide the length (mm) of each leaf for each observation by the length of the mature leaf (mm) at the end of the observations, and multiply by 100. By doing these calculations of percent leaf growth, students will be able to compare leaves that have different leaf lengths at maturity. (Note: a facsimile of the data sheet and graph are available on the GLOBE web site (www.globe.gov).

Step 3. “Green-Down” or “Senescence”

In the fall, you need to start the green-down a few weeks before the leaves normally start to change color. Again, you will need to select a branch on each of your trees and label the leaves in the same manner as you selected branches and labeled your buds in the paragraph above. It would be super if you can use the same branch used for green-up. Once your four leaves from each of your trees are selected, your students can begin observing and recording data. If you join GLOBE’s phenology study, students will need the GLOBE Plant Color Guide to successfully collect this data and publish their findings on the web.

Performing the GLOBE Plant Phenology Protocol for Grasses in Treeless Areas such as Tundra Ecosystems in Northern Latitudes

Step 1. Site Location

Select a one-meter square area dominated by grass plants, ideally native species, and not fertilized nor irrigated, and mark it with nails or stakes or other durable identifiers. Try to have the site at least 100 meters away from any building. Identify the genus and species using field guides or the help of plant specialists. Take a GPS reading to determine the exact location of the site. Finally, take a photograph from the center of your site to the north, south, east, and west directions. You now have your GLOBE phenology site for grasses.

Step 2. Green-Up

Look for new green grass shoots and mark the base of the first grass shoot with a single dot when you first find it. Mark the second shoot with two dots, the third with three dots, and the fourth shoot with four dots. Visit the site twice weekly. Use the mm ruler to measure the length of the shoots. Keep measuring the grass until the shoot length stops increasing.
Step 3. Green-Down

Return to your grass plot in late autumn. Look for the four longest green grass shoots. Mark the base of the longest grass shoot with a single dot, the second shoot with two dots, the third with three dots, and the fourth shoot with four dots. Visit your grass plot twice weekly and record the color of the leaf using the GLOBE Plant Color Guide until the leaves have changed from green to other colors or when the grass plants are completely covered with snow.

Framing a Long-Term Phenology Study with Deciduous Trees

The first author’s students live in a heavily industrialized and urban area of what used to be a part of the Great Lakes Hardwood Forests. Although the growing conditions for trees may be less than ideal, a variety of trees does add grace and beauty to our cityscape. Twenty trees on our urban campus make up our phenology sites. We allow only one student at a time with a set of students, our students do either the green-up or the green-down data collection but not both. This ongoing sharing of data helps reinforce the idea of groups of scientists working together to build a more comprehensive database.

Recording the green-up and green-down data gives us both the duration and particular start and finish time of the growing season for each tree in our study. Once we have the data, we ask our students to look for patterns and perhaps be able to answer questions such as:

1. Do older trees of the same species have a longer growing season than younger ones?
2. Do certain tree species have longer growing seasons than other species?
3. Do trees that are shaded on the north side by buildings have a longer growing season than trees of the same species completely out in the open?

Each year that we add data helps our current students test previous hypotheses and add new ones. Thus, students are learning experientially about the nature of science by generating and refining hypotheses from data they helped collect. Finally, having students responsible for collecting data on a particular tree can have an affective bonus; trees have a majesty of their own and learning to appreciate them more fully is valuable in an environmental science or biology classroom.

Conclusion & Extensions

Performing the GLOBE plant phenology protocols in our classroom provides a ready-made long-term scientific study. By following the GLOBE protocols, we build a body of data semester-by-semester and year-by-year that is accurate, consistent, and long-term. These data are used to help students generate and test hypotheses like “real” scientists and build on the work of previous students.

The study can be enriched further by incorporating data from the GLOBE website (www.globe.gov). Since the phenology protocols are new, however, relatively small amounts of data are currently available. As more GLOBE-certified teachers become informed of the new plant phenology protocols, however, more data will be added and more student-directed inquiry generated. If you are a GLOBE-certified teacher, your students can add directly to the GLOBE data bank and contribute to the much needed ground reference data for remotely sensed data. As college instructors, we invite our undergraduates to work with K-12 GLOBE students in collecting plant phenology data as a service-learning project. Our students tell us that sharing their newly gained expertise in this fashion helps make their learning “authentic” indeed.

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References


