

❖ Teacher Notes ❖
for
The Apprentice's Companion
for
Environmental Science

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Teacher Notes for The Apprentice's Companion for Environmental Science

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General Notes

The ACEnS lab book follows the order of chapter topics in the Environmental Science textbook, but depending on your local context, consider moving some activities. For example, if you live in a climate where winter field work would be a frozen adventure, I suggest introducing stream ecology and water quality testing near the beginning of the school year when the weather may be better for a field trip.

There are several outdoor activities that can be expanded to serve as long term projects for a quarter or the entire school year. Regular field sampling demonstrates to future environmental science professionals the value of baseline data and consistent seasonal monitoring. Examples of possible long term projects include biodiversity surveys (Activity 2), aquatic macroinvertebrate sampling (Activity 9), water quality testing (Activity 26), and terrarium management (Alternate Activity 1).

On Practicing Stewardship (campus projects, field trips, environmental advocacy, university programs with a stewardship focus)

On Campus

- Create and maintain native plant communities
- Plant vegetable gardens and mini-orchards
- Develop or improve school-wide recycling and composting programs
- Connect with your administration's strategic plan and brainstorm ways your students can participate, while advocating for a lighter ecological footprint

In the Community

- Participate in or facilitate restoration projects or creek clean ups for students
- Design field trips to local natural areas, family farms or water treatment facilities
- Volunteer with your class to assist local environmental advocacy groups
- Connect with a local residential outdoor education program ("science camp")

Further Afield

- Lead or hire local experts for overnight high school wilderness trips. Paul Harris, a veteran hands-on science teacher and friend of mine in Redmond, Oregon, uses a "Mountain Classroom" model that stretches high school students out of their comfort zones and creates unforgettable, life-changing overnight experiences out in the high desert. If you would like advice on how to create a similar experience at your school, Paul's contact info is paul.harris@oregonfamilyschool.com.
- If your high school offers international service or missions trips, consider planning them with a stewardship focus woven into the service objectives. When I take The King's Academy students on Belize service trips, I intentionally include some outdoor education in the tropical rain forest, in addition to their primary service projects at a local underserved elementary school. We try to stay in ecologically conscious places like Jaguar Creek (jaguarcreek.org) or Monkey Bay Wildlife Sanctuary (monkeybay-belize.com).

College Programs

- Encourage your highly motivated environmental science seniors to consider applying to universi-

ties that have robust environmental science majors or minors. Some well-known examples among Christian universities are Westmont, Biola, Azusa Pacific, Point Loma, Calvin, Messiah, Trinity (BC), Houghton, Malone, Olivet Nazarene and Southern Nazarene. Northwestern Nazarene University (NNU) in Idaho recently began offering a new wildlife biology and ecology major, and the contact professor is Dr. David Hille at dhille@nnu.edu.

- While attending college, students can also spend a May or June short course at Au Sable Institute for Environmental Studies in northern Michigan (upper peninsula) or Washington (Whidbey Island). Professors with strong stewardship values from Christian universities all over the country teach field research courses for Au Sable on a rotating schedule. Check them out at <https://www.ausable.org/college>.
- Finally, college students in environmental science or biology majors can spend an entire semester in a stewardship and science focused study abroad program. Examples include the Quetzal Education Research Center in Costa Rica run by Southern Nazarene University (<https://qerc.snu.edu/>) and the Creation Care Studies Program in New Zealand (<https://www.creationcsp.org/>).

Activity 1 Dandelions and Hula Hoops

Rather than using hula hoops, consider cutting and gluing PVC pipe and elbows into squares to create 1 m² quadrats. This makes the students' calculations and population estimations less challenging. Map and grid out the entire study area online, using a random number generator to choose which 1 m² quadrats to sample.

To introduce another sampling technique, stretch out 10-m-line transects with string or rope in a forest or unmanaged field. Choose habitats with variable light, water, or proximity to roads to draw out comparisons between student groups. A line-transect activity is a great way to learn about environmental variation while sampling local plants, arthropods or birds.

Example diagrams and images:

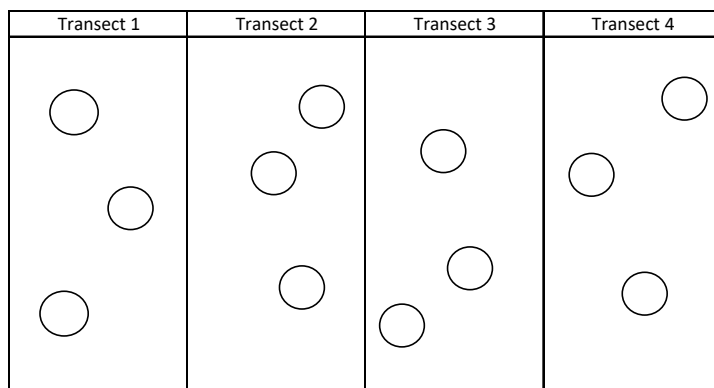


Figure 1: Sample belt transects with hula hoops randomly placed in grass.



Activity 2 Backyard Biodiversity

Example images:





Activity 3 Food Webs and Stewardship

Tips:

Another great connection involves students giving back their organism cards while still holding to the yarn in the network they created. Now, each point of the web is being held by a person, gifted in diverse ways, loved unconditionally, each a unique and indispensable part of the community.

This activity can also be used as an icebreaker at the beginning of the school year. Ask students to verbalize what makes them unique, or what their interests are, or who they hope to be when they graduate high school or college.

Homeschool tutors can make this activity work by including other family members or friends to make up a group.

Organism Cards

The 20 generic examples listed below should produce clear connections across multiple trophic levels. However, I recommend creating your own laminated cards with specific plants and animals that students may recognize from your local region. I recommend printing a photo of each organism on one side of the card, and the common name on the other side.

Abiotic Cards

Sun, Soil, Water

Biotic Cards

Bacteria, Fungi, Earthworm, Ant

Tree, Plant, Leaves, Flower

Honeybee, Hummingbird, Caterpillar, Mouse, Deer

Robin, Snake, Hawk, Mountain Lion

Activity 5 Climate and Biomes

You will find the four data sets in your MyLibrary account for *The Apprentice's Companion for Environmental Science* in the Excel file titled "Biome (Act 5) Datasets.xlsx." You can open this file in Microsoft Excel or in Google Sheets.

Both Google Earth and Biomeviewer are free to the public and great resources for learning about the interaction of climate, biomes, and human impacts. Google Earth is an easy, fun way to engage students with this topic at the beginning of the lab. You can zoom in on the tropical rain forest in the Congo or the Atacama Desert in Chile as you talk about global distribution of biomes. Then you can zoom in on your state, then local area, then school (or home), noting the biomes and human impacts along the way. In the Biomeviewer app, students can choose a place they are interested in, drop a pin, and see biome & ecological info from that area, including a climograph and common flora/fauna.

Also listed are two other online resources that may be useful extensions of this activity. Arizona State University has a well-organized virtual biome activity that drops you in various biomes all over the world, and it includes relevant sound effects and scientists in the field. NOAA's climate.gov website allows users to pull up climate data and generate climographs from thousands of weather stations across the US.

Below is the climograph data for the city comparisons, from www.worldclimate.com.

	San Francisco, CA		Atlanta, GA	
Month	Mean Monthly Temperature (°F)	Mean Monthly Rainfall (in)	Mean Monthly Temperature (°F)	Mean Monthly Rainfall (in)
January	51.1	4.4	41.0	4.6
February	54.3	3.0	44.8	4.6
March	54.9	3.1	53.4	5.5
April	55.9	1.3	61.3	4.1
May	56.5	0.4	69.1	4.0
June	58.3	0.2	75.9	3.6
July	59.0	0	78.8	5.3
August	60.1	0.1	78.1	3.6
September	62.2	0.3	72.7	3.6
October	61.9	1.1	62.2	3.0
November	57.2	2.9	53.1	3.7
December	51.6	3.6	44.4	4.1
Year	56.8	20.4	61.2	49.8

	Hilo, HI		Phoenix, AZ	
Month	Mean Monthly Temperature (°F)	Mean Monthly Rainfall (in)	Mean Monthly Temperature (°F)	Mean Monthly Rainfall (in)
January	71.6	9.0	51.6	0.8
February	71.6	11.5	55.6	0.7
March	72.0	14.0	61.0	0.7
April	72.7	13.8	68.4	0.3
May	73.8	9.5	76.5	0.1
June	75.2	6.3	85.6	0.1
July	75.7	10.0	91.0	0.9
August	76.3	10.7	89.2	1.0
September	76.1	7.8	83.5	0.8
October	75.6	9.7	72.0	0.5
November	74.1	14.6	59.7	0.6
December	72.3	11.1	52.7	0.9
Year	73.9	128.1	70.5	7.6

Climograph Data from Four US Cities (1960–1995)

Other Resources:

<https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/national/time-series>

<https://en.climate-data.org/>

<https://www.biointeractive.org/classroom-resources/biomeviewer>

<https://askabiologist.asu.edu/explore/Virtual-360-Biomes>

Biome pictures:



Colorado Temp Conifer Forest



Southern Arizona Desert



Redwood Forest

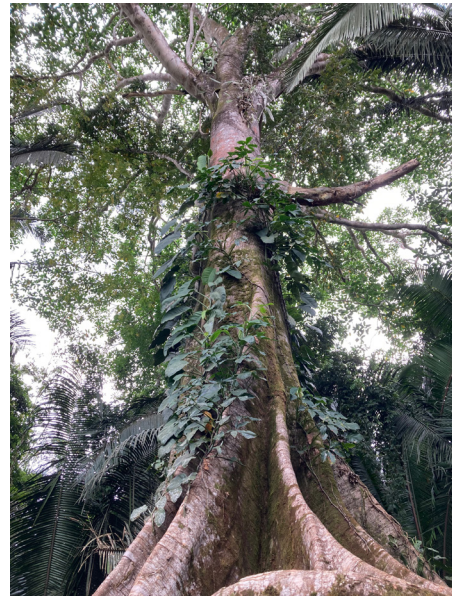


Fig in Tropical Rain Forest, Belize

Activity 6 What Will Transpire?

Small plants like impatiens, geranium, or begonia that come in little 6-packs at the local garden center usually give the expected results for transpiration. Make sure students tie their plastic bag snugly around the base of each plant so that evaporation from soil is minimized.

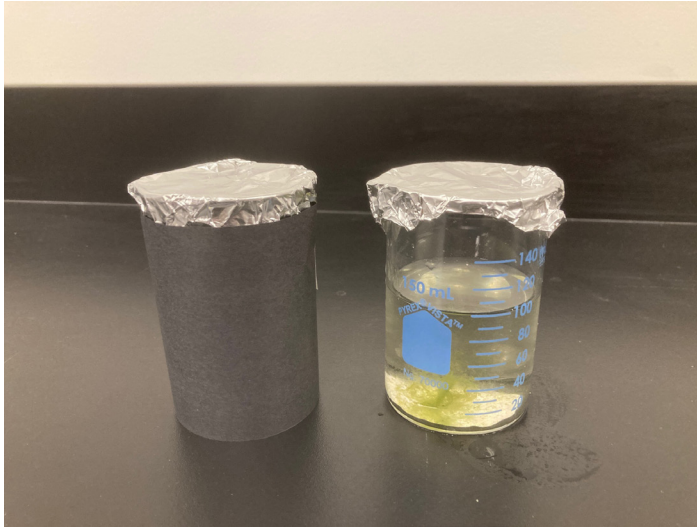
Activity 7 Algae Adventures

One great extension to this lab is the addition of a small snail into the algae water samples. Dissolved oxy-

gen readings should decrease as the snail undergoes cellular respiration and consumes oxygen.

For the light source in this activity, a grow light is best. However, a 60–100 W incandescent bulb or an LED bulb of 1300–1600 lumens will work as well.

Instead of using black paper to make the dark bottle, you can use one transparent bottle and one opaque bottle.

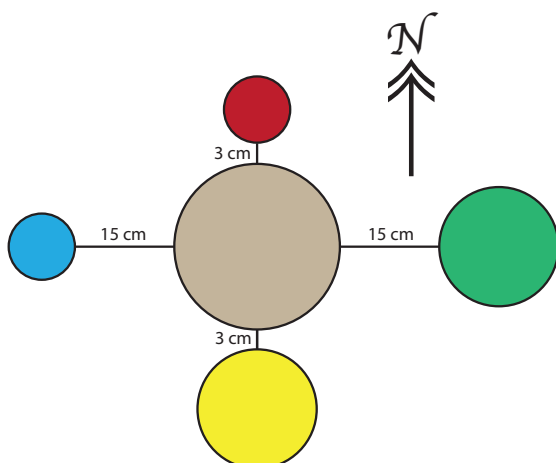


Activity 8 Bean-Bag Biogeography

Corn-hole game:



As described in the book, the layout for the bean drop looks like this:



Alternatives

If corn hole equipment is not available, consider using sidewalk chalk to create large and small islands at various distances from the “mainland,” from which you can toss the bean bags using the corn-hole rules. If no bean bags are available, other objects can be used as “colonizing species.”

A simple field-sampling activity can also demonstrate some of the predictions of island biogeography. As in Activity 1 (Dandelions and Hula Hoops), record species richness by means of field identification of plants growing with grass in a local field. In this case, hula hoops can represent larger islands and smaller circular plots made of rope can represent smaller islands. Results usually produce higher levels of biodiversity in the larger circular plots, depending on the overall level of plant diversity at your sampling site.

Activity 9 Living Waters

The Pollution Tolerance Index Sheet in this activity comes from the Children’s Discovery Museum in San Jose, California and can be accessed at <https://www.cdm.org/biosite/assets/pollution-tolerance-index-data-sheet.pdf>.

Here are some links to several online macroinvertebrate identification keys:

Stroud Water Research Center at <https://stroudcenter.org/macros/key/>

Macroinvertebrates.org at <https://www.macroinvertebrates.org/key/>

Water Quality Mobile App at <https://wikiwatershed.org/water-quality-app/>

Related images:



Water strider



Savegre River, Costa Rica

Activity 10 Squirrels and Oaks

Many versions of this carrying capacity activity are used in environmental science courses, but it was originally adapted from Rosenthal, Dorothy B. *Environmental Science Activities*, John Wiley & Sons. 1995.

Related images:



Activity 11 Nest Predators

This simulation game is rooted in outdoor education camp traditions and is also called “Jays & Juncos.” I modified the game to include recording of the annual breeding success data with a post-game follow up graph of the results. I used crows and warblers as the players in the game, but depending on your local context, you can switch out the species as needed.

An extension to add complexity to the simulation for older students is to mark 10% of the white beans

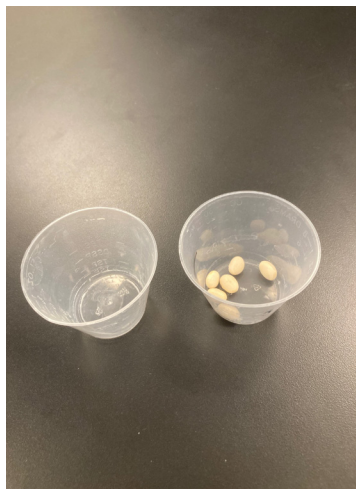
with a red dot, modeling the negative impact of pesticides on egg hatching success. If the students are unaware what the red dot means, they will pick them randomly, finding out later that pesticide further reduces the warblers' breeding success.

With older students, each generation round should last two minutes. If this activity is being done with younger students, allow five minutes per round.

With clear instructions and supervision, this game can be played effectively at all age levels, but any cheating will affect the data and produce less than desirable results. Warblers cheat by concealing their nest in an impossible to reach location. Crows cheat by focusing only on certain warblers (their friends), instead of randomly searching for nests.

You can model the effects of pesticides by adding red dots from a permanent marker on a percentage of the white beans. When students count their eggs, the ones with red dots did not hatch, and therefore cannot count toward their total for the season.

Images:

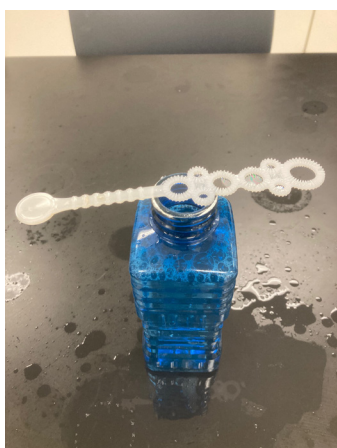


Raven

Activity 12 Bubble Survivorship

To the untrained eye, this activity looks like a bunch of students running around chasing bubbles. In my experience, I have communicated with fellow teacher and administrators to explain that students are actually collecting demographic data and generating survivorship curves. It is one of the most memorable labs for students, especially the ones who learn more effectively in the outdoors.

Images:



Activity 13 Grave Consequences

Homeschool students can easily manage this activity by recording 30 names in each category instead of 10. Images from a historical cemetery in Savannah, GA.:





Activity 14 Power Trip

Image of an electric meter:



Activity 15 Here Comes the Sun

The pizza box method is a relatively simple and safe way to experiment with solar-energy cooking and collaborative engineering design. However, for an added challenge, consider the value of not using a step-by-step “cookbook” procedure. With the appropriate basic materials to assemble a functional solar cooker, student groups may engineer some brilliant designs that are more efficient than the pizza-box method.

S’mores are encouraged for a first solar-cooking experience because the heat required must simply melt the chocolate and soften the marshmallows. For challenges with longer cooking times, try warming up fully cooked hot dogs or baking cookies from dough. These cooking projects may take several hours, depending on the intensity of sunlight in your area, time of day, and season, but generally expect 40–60 minutes.

Below are sun images the author wanted to share.



Keys View at Joshua Tree NP



Sunrise, Tybee Island, GA



Westpoint Harbor

Activity 16 Oil and Trouble

Because even a small amount of “dispersant” (dish soap) is very effective, it is a good idea to withhold that mitigation method until after the other methods have been tried. It creates a wow factor that can be missed if students are allowed to use it from the beginning.

Another twist that creates more of a challenge for more experienced students is the addition of a current in the baking pan before the oil spill is poured. Slowly swirling the water with a pipette around the perimeter just before pouring the oil causes the spill to be more rapid in its approach to the island.

A meaningful extension of this activity is the investigation of bioremediation using oil eating bacteria.

Here is one example of a kit from Flinn Scientific: https://www.flinnsci.com/oil-eating-bacteria---student-laboratory-kit/fb1200/?srsltid=AfmBOop_z0w9FKXGoJyZZA8hk8K8QhjYU18KBEKXEE4udr5jM-LdANBcs

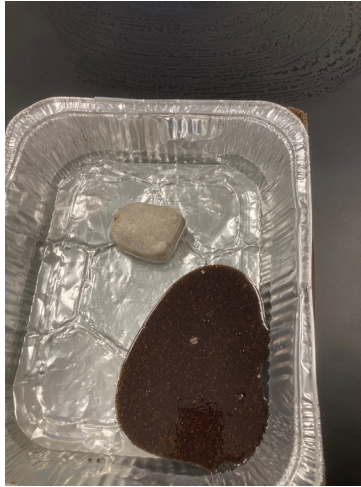
Flinn only sells to institutions, so here is a similar kit from Carolina Biological:

<https://www.carolina.com/carolina-ecokits/oil-spill-bioremediation-kit/181324.pr>

Images:



Oil boom of straws.



Oil spill model.



Oil spill reaching island.



Oil spill suction.



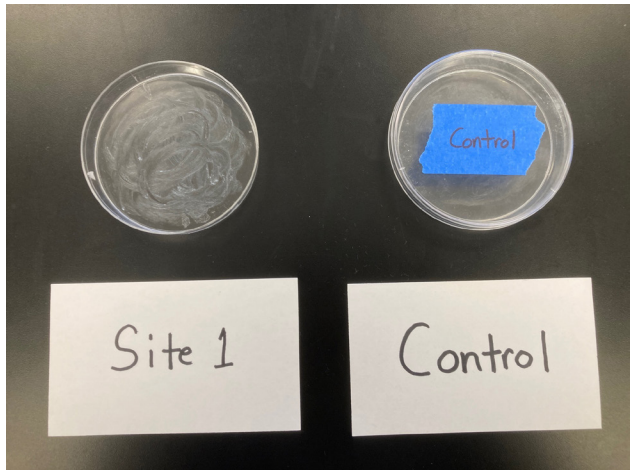
Oil spill skimming.



Close up of oil boom.

Activity 17 Coughing Up a Storm

Images:

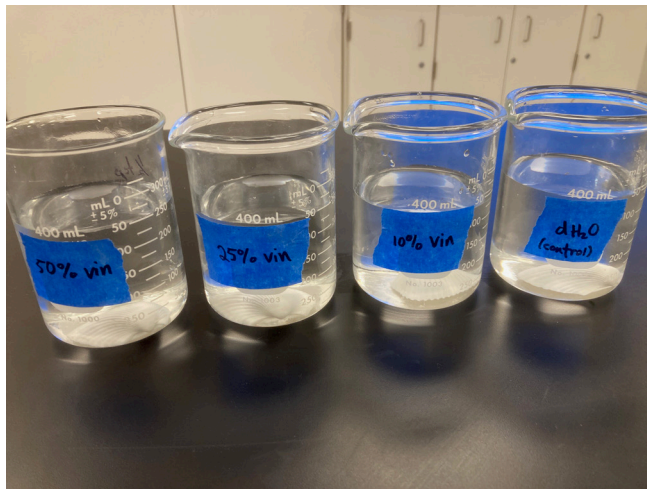


Particulate dishes.



Wildfire smoke.

Activity 21 No Seashells by the Seashore



Shells in vinegar.

Activity 22 Revelations of the Rings

If needed, tree cookies can be purchased from science supply companies. However, obtaining tree cookies from a local farm with known year of harvesting is advised, and those rings may show interesting variation based on relatively recent local weather patterns. Mr. Smithson says he has never had a tree farm say no to free tree cookies.

Also, the University of Arizona Dendrochronology Lab has tree cookie kits that can be borrowed by teachers. Visit <https://ltrr.arizona.edu/content/science-kits-loan> for more details.

Activity 23 Dirt Don't Hurt

Coffee filters may be substituted for filter paper, and jars for beakers.

Student soil samples from yards can be unpredictable, so it is suggested to create a soil sample for use in the lab with all three particle sizes represented. Some teacher research on expected soil profiles in your local area will be very helpful as you attempt to compare expected outcomes with the students' soil sample results.



NPK tests.



Particle size demonstrations.

Activity 24 Soil Is Life

This activity is designed for three different lab groups to test three different sugar concentrations. If only one group or student is working, use four containers and four Petri dishes so that all three sugar concentrations are tested. Alternatively, test the control and one sucrose solution concentration on days 1–2, and the other two sucrose concentrations on days 3–4.

To make 90 mL of 10% solution (by mass), dissolve 10 g sugar in 90 mL (90 g) water. To make the 1% solution, cut the 10% solution 10:1. Alternatively, dissolve 1 g sugar in 99 mL (99 g) water. Similarly, for 0.1% dissolve 0.1 g sugar in 99.9 g water.

Activity 25 Salty Plants

To make 98 mL of 2% salt solution, dissolve 2 g NaCl in 98 mL (98 g) distilled water. To make 1% solution, mix equal parts 2% solution and distilled water. To make 0.5% solution, mix equal parts 1% solution and distilled water.

Activity 26 Watershed Moments

There are many different water-quality tests, as well as a great variety of test kits and instruments.

For those who will be performing this activity year after year, consider investing in water testing probes from Vernier or Pasco. Both these suppliers have a wide variety of probes for different tests. For single use, a good testing kit is the Earth Force kit from LaMotte:

<https://lamotte.com/products/environmental-science-education/water-monitoring-kits/water-monitoring/earth-forcer-low-cost-water-monitoring-kit-3-5886>

This kit includes all the tests described in the lab activity except conductivity (TDS).

The Vernier conductivity probe is super easy to use and costs \$129:

<https://www.vernier.com/product/go-direct-conductivity-probe/>

At the link above, there is a demonstration video showing how simple it is to use the probe. For this activity, conductivity values can be measured right in the field, if desired, by using the Bluetooth feature to connect the probe to a smartphone with the free app installed.

Activity 29 Trash Talk

Some families might not be thrilled with the idea of their students digging through the trash, collecting and counting items. Emphasize the importance of wearing protective gloves and washing hands thoroughly after handling trash.

College Board's APES Lab #17 (Decomposition in a Model Landfill) is credited for the experimental design that includes measuring and comparing the size of decomposing objects through the glass of the beaker. For more detailed landfill design information, check out "The Hidden Engineering of Landfills," from Practical Engineering at https://www.youtube.com/watch?v=HRx_dZawN44.

Image:



Puente Hills landfill.

Activity 30 This Land Is Your Land

Many thanks to the helpful and passionate Naturalists and Directors at Mission Springs Outdoor Education (<https://missionspringsoe.com/>) for allowing me to use their “Town Council” template to modify and adapt for this lab book.

To expand upon this land use activity, consider investigating your local region’s indigenous history and encouraging student reflection on historical and present realities for indigenous peoples. At the least, I suggest using the appropriate name for the “Native American tribal community” stakeholder group in the simulation. Use the website Native Land Digital to pull up a teachers’ guide and maps at <https://native-land.ca/resources/teachers-guide>.

Ten Alternate Activities

1. Mini-ecosystems (Ch 3)

- Engineer a self-sustaining terrarium with aquatic and terrestrial components
- Investigate ecosystem energy dynamics using dissolved oxygen levels
- Compile and analyze long term data sets on soil chemistry and water quality

<https://teachingapscience.com/everything-ecocolumns/>

2. Convection Currents (Ch 3)

- Discover influence of global convection currents on atmospheric circulation

- Construct several models demonstrating the effects of oceanic convection currents
- Investigate influence of the El Niño phenomenon on global atmospheric patterns

<https://scied.ucar.edu/activity/convection>

3. Conservation Biology Poster Session (Ch 4)

- Discover stewardship in action connected to selected conservation biology projects
- Collaborate to research, create, and present project in “walk around” poster session
- Provide constructive feedback and ask thoughtful questions about other posters

4. Population Pyramids (Ch 5)

- Investigate and compare age structure pyramids from developed and developing world
- Using online population data, create two comparative age structure pyramids
- Relate age structure differences to cultural and socioeconomic realities in each country

<https://populationeducation.org/resource/power-of-the-pyramids-video/>

5. Biodigester Activity (Ch 6)

- Investigate historic and current global biomass energy use
- Design a simple methane producing biodigester model
- Compare efficiency of biodigester models under differing conditions

https://www.teachengineering.org/activities/view/usf_biorecycling_lesson01_activity1

6. Ice Core Activity (Ch 8)

- Learn about the extraction and deciphering of ancient Antarctic ice cores
- Connect long term data sets on atmospheric CO₂ levels with specific ice core rings
- Build a model of a hypothetical ice core showing the rise and fall of atmospheric CO₂

<https://sciencelessonsthatrock.com/teaching-climate-change-with-ice-cores-html/>

7. Cookie Mining (Ch 9)

- Track natural resource depletion rate with model mining simulation
- Collaborate with peers in management of natural resource acquisition
- Develop environmental mitigation strategies to protect and restore land

<https://www.teachengineering.org/activities/view/ncs-2031-cookie-mining-cost-benefit-analysis-analysis-profit>

8. Food and Agriculture Activity (Ch 9)

- Investigate origins of common fruits, vegetables, meat and dairy products
- Dissect and compare origins of a veggie pizza vs. a pepperoni pizza

- Discuss agricultural methods used and transportation energy required

9. Water Filtration (Ch 10)

- Collaborate with engineering team to construct water filtration with given materials
- Test pre- and post-filtration water samples for turbidity and dissolved oxygen levels
- Discuss importance of high regulatory standards in drinking water quality

https://www.teachengineering.org/activities/view/cub_waterqtnew_lesson01_activity1

10. Ecological Footprints (Ch 11)

- Compare and contrast ecological footprints of developed and developing countries
- Using data from energy and water use audits, calculate personal ecological footprint
- Compare personal ecological footprint with individuals in developing countries

<https://www.footprintnetwork.org/our-work/ecological-footprint/>

Useful Website References

College Board's AP Environmental Science course (must teach course to access)

<https://apcentral.collegeboard.org/courses/ap-environmental-science/classroom-resources/labs>

Great Lakes Bioenergy Research Center (soil microbial activity, biofuels, etc)

<https://www.glbrc.org/outreach/classroom-materials>

Population Education (human population dynamics)

<https://populationeducation.org/>

Science Lessons That Rock (many topics)

<https://sciencelessonsthatrock.com/blog/>

Stroud Water Research Center (aquatic ecology)

<https://stroudcenter.org/education/>

Switch Classroom (energy)

<https://switchclassroom.org/>

Teach Engineering (many topics)

<https://www.teachengineering.org/>

Teaching AP Science (many topics)

<https://teachingapscience.com/>