

The Apprentice's Companion for

S ENVIRONMENTAL Science



NOVARE

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Scott Smithson



The Apprentice's Companion for Environmental Science
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One of Scott Smithson's fondest memories is the day his Kindergarten teacher gave him his first field guide to birds. Scott spent much time outdoors while growing up, birding and surfing in the small town of Pacifica, California. He earned his Bachelor of Science in Biology from Biola University, where he was inspired by engaging instructors and hands-on experiences in the lab and field. He earned his Master of Science in Biology from California State University, Long Beach, where he conducted his thesis research on the breeding biology of the Nutmeg Mannikin and Orange Bishop, two recent introductions to the southern California avifauna.

After graduate school, Scott served for six years as Director of Mission Springs Outdoor Education, a residential outdoor school in the redwood forests of the Santa Cruz Mountains. During this time, he experienced the joy of teaching and mentoring young college graduates as they learned how to teach ecology and environmental stewardship to middle school students. Scott has been teaching for the last 11 years at The King's Academy, a Christian high school in Sunnyvale, California. He teaches AP and General Environmental Science, AP Biology, and Marine Science, as well as serving as a Science Department Co-Lead.

Scott met his wife Dawn while attending an undergraduate semester abroad in the Latin American Studies Program in Costa Rica. After graduation and a wedding in Pacifica, they spent their first year of marriage serving as the first Directors of Jaguar Creek, a Christian environmental education center in Belize. Scott and Dawn have been married for nearly 30 years and love raising their two teenaged children. Scott enjoys hanging out at home with family, going on birding adventures with friends, and leading student service trips to Belize.

Introduction

Some things cannot be learned easily—or at all—from books. This is what apprenticeships are for—to provide learners a context in which skills and knowledge are acquired by direct modeling, mentoring, and practicing. Everyone knows about the apprenticeships that were part of the system of guilds back in the Middle Ages. Some of the terminology from those times survives in the trades today. Plumbers and electricians are rated in terms of Apprentice, Journeyman, and Master. But today, even some professional careers include apprenticeships: attorneys obtain clerkships to gain the experience needed to become judges. Medical school graduates obtain residencies to acquire the hands-on experience of caring for patients that cannot be transmitted through books.

In a similar way, science classes can convey the principles, concepts, and mathematical models associated with scientific inquiry and scientific theories. But laboratory skills, which are so important for understanding how science works and how scientific hypotheses are put to the test in experiments, must be acquired through hands-on laboratory work. This is why it is appropriate to think of the lab activities associated with a science class as an apprenticeship in which students acquire knowledge and skills that are not easily acquired by reading books.

Thinking of labs as apprenticeship one of the reasons why this book is called *The Apprentice's Companion*. The other reason is that in conceptualizing this manual of experiments and activities, we have departed from the formatting and content typically found in books of experiments. We thought it would be more interesting and more consistent with the tenets of classical education to create a multi-disciplinary environment in which students could enjoy literature, poetry, history, and art right along with their science. Accordingly, we have integrated items into these pages from across the arts and sciences that we hope students will find amusing, fun, and intellectually stimulating.

One of our reasons for calling the book a companion is that we aim to enhance the value of the book for the student. This volume combines the functions of experiments manual, lab journal, sketchbook, and commonplace book:



Experiments Manual. This book includes the procedures students need for conducting 30 experiments and activities during their study of Environmental Science.



Lab Journal. The lab journal is the place to record scientific observations and data collected during laboratory exercises. It can also be used for setting up graphs of data that can reveal underlying patterns in the data that help us interpret what the data tell us about how nature works. Students won't need a separate lab journal to accompany this course—it's built right into this book.



Sketchbook. A sketchbook is a place to draw, practice drawing, and refine one's drawing. As depicted in the movie *Master and Commander* a few years back, there is a long tradition in which naturalists—those engaged in what used to be called natural history—develop refined drawing skills and put those skills to use documenting the natural world around them—the bugs and buds, leaves and leeches, trees and turtles in the world that we can marvel at and study.



Commonplace Book. A commonplace book is a place to record thoughts, discoveries, questions, observations, quotes, events, mysteries, conundrums, meditations, references, words, witticisms, riddles, prayers, queries, and all the other strands that weave themselves around in an active and developing student's mind. The keeping of a commonplace book is a tradition central to classical education, dating back centuries. Hundreds of famous authors kept commonplace books, trained to do so at institutions such as Harvard College and Oxford University. For help understanding what a commonplace book

is all about, check out the YouTube video by Jordan Clark entitled “you should start a commonplace book.” At the end of that video, Jordan shares this quotation from Jonathan Swift:

A commonplace book is what a provident poet cannot subsist without, for this proverbial reason, that ‘great wits have short memories’ and, on the other hand, poets, being liars by profession, ought to have good memories; to reconcile these, a book of this sort is in the nature of a supplemental memory, or a record of what occurs remarkable in every day’s reading or conversation. There you enter not only your own original thoughts, (which, a hundred to one, are few and insignificant) but such of other men as you think fit to make your own, by entering them there.

Supporting Text

The Apprentice's Companion for Environmental Science, by Scott Smithson, is designed to accompany *Environmental Science*, by Mark McReynolds and Karen McReynolds, published by Novare Science and Classical Academic Press (2025).

Teacher Notes

To accompany *The Apprentice's Companion for Environmental Science*, Classical Academic Press has available a downloadable PDF of Teacher Notes. This PDF is available online for purchasers of this book at the My Library page of the purchaser’s online account at Classical Academic Press (classicalsubjects.com). The Teacher Notes contains information about activity guidelines, supply substitutions, sample photos of activities in progress, and other items.

Materials and Equipment

The purchaser’s My Library account mentioned above also contains a spreadsheet itemizing all materials required for these laboratory activities, as well as costs and suggested suppliers. To make acquiring supplies as convenient as possible, online supplier Home Science Tools (homesciencetools.com) has a kit of supplies designed to support this book.

Equipment Substitutions

We recommend that students use actual lab apparatus, whenever possible. However, for those on a tight budget, many substitutions may generally be made: you can substitute plastic spoons for glass stirring rods; glasses, glass jars, or bowls for beakers; coffee filters for filter paper; small bowls or saucers for Petri dishes; and so on. You will still need two sizes of graduated cylinders, a mass balance, a microscope, a thermometer, a water-quality test kit, and a few other items. Most of the other materials used in these activities may be procured at a grocery store. Note that kitchen-type Pyrex containers should never be used for heating. When heating any liquid, always use a borosilicate-glass container.

Scales

For weighing substances precisely in this course, students require a mass balance with resolution of at least 0.1 g. However, studies in chemistry typically require a scale with 0.01 g resolution. These days, there is not much cost difference between the two, so we have recommended a 0.01-g scale in the materials list. (See the Materials spreadsheet referenced above.)

Microscopes

A few activities call for a stereo microscope. For this course, one can get by with a hand magnifier if a microscope is not available.

Thermometers

Digital thermometers with resolution to 0.1°C are preferred. However, glass alcohol thermometers with 1°C resolution are also acceptable.

Writing Lab Reports

Does the creation of this *Apprentice's Companion* mean that students don't need to write lab reports? Absolutely not!

The *Apprentice's Companion* is not a substitute for writing lab reports—an important skill students must continue to practice, year by year. Novare Science has consistently recommended that students write five or six full lab reports each year. The same applies to our Environmental Science course. Instructors should simply select three of the activities performed during each semester and designate these as the activities for which full lab reports will be written. The essential guide for writing lab reports is *The Student Lab Report Handbook* by John D. Mays, available from Novare Science and Classical Academic Press.

How Many Labs to Do?

For many school classrooms, completing all the activities in this book will not be possible in a single class year. Others, such as home schoolers, have more flexibility. We recommend working at least 24 of the 30 included activities into your course schedule. Of course, if you can make time, do them all!



On Natural History, Observation, and Sketching

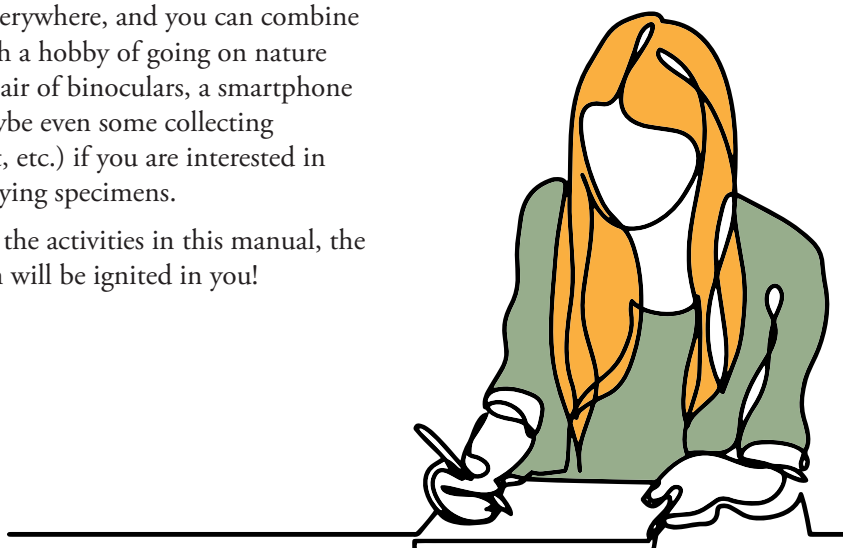
Modern scientific study grew out of the classical tradition of Natural History, which goes all the way back to Aristotle. Eighteenth- and nineteenth-century literature is full of references to natural historians and their work. Natural historians observed nature deeply, made careful and accurate sketches of organisms, collected and preserved specimens, and identified species (or named newly discovered ones). During the activities in this manual, you will do all these things and more.

But we want to encourage you to go beyond the activities described here and consider becoming a natural historian yourself. Observing nature is fun, relaxing, and rewarding. There is no end to the fascination one can experience by watching birds, lizards, insects, and other animals. In the past, many writers could readily identify all the native plants, birds, and other animals in their area. You can make it a project of your own to learn the names of the plant species where you live. Just think how much fun it would be to one of the few people walking around in your neighborhood who knew all the names of the plants! It's not hard, and a smartphone app such as NatureID makes easy work of identifying plants. The Merlin Bird ID app from Cornell University is the perfect tool for identifying birds.

Making sketches is also great fun, especially if you take the time to learn how to make accurate, beautiful drawings. The only real requirement is something to draw and lots of practice. Sketchbooks are available at most bookstores, and making sketches of plants, trees, birds, land animals, and grasses is relaxing and rewarding.

Finally, there are natural trails everywhere, and you can combine an interest in natural history with a hobby of going on nature hikes. Take your sketchbook, a pair of binoculars, a smartphone with the apps you need, and maybe even some collecting equipment (bags, containers, net, etc.) if you are interested in collecting, mounting, and displaying specimens.

We hope that as you go through the activities in this manual, the old spark of the natural historian will be ignited in you!



— Commonplace Space —

Students, as you begin this course of study, take time to pause and reflect. Embrace this educational experience as your own journey. What might you gain? What questions do you have going in that you would like to find answers for? What stories have you heard about the study of the environment that inform your own goals? In what ways can this study help you to grow at this particular time in your life? Take time to reflect on these things as you enter this new course of study and write down your thoughts!

A large grid of small circles, arranged in 20 rows and 40 columns, intended for students to write their reflections in.

Activity 1

Dandelions and Hula Hoops

Today's Date _____

General Information

Environmental Science text reference: Chapter 1

Estimated time: 1 hour

Activity type: field data collection



Introduction

Imagine being given the job of counting all the squirrels in a big oak forest, finding every bullfrog in a large wetland area, or investigating how many aphids are living in an entire rose garden. These sound like very difficult and time-consuming tasks!

Environmental scientists recognize the importance of monitoring the population dynamics of sensitive species. To determine whether a population of plants or animals is expanding or contracting, environmental scientists need to know approximately how many individuals are present to establish a baseline number from which to measure. However, depending on the size of the study site and the detectability of the organisms, it may be impossible to get a direct count of a population. Thanks to a research technique called random sampling, we don't have to count every individual in order to estimate the total population size.

In this field research activity, you practice observation skills and ecological sampling methods on a grass field at your school or in a local park. With the help of hula hoops and your math skills, you can estimate the total population size of dandelion plants at your study site without having to count every plant.

Objectives

-  Sharpen observational skills by identifying and counting organisms.
-  Practice the foundational research technique of random sampling.
-  Use math skills to estimate the total population.

Materials (per group of 3–4)

-  hula hoop
-  measuring tape
-  chalk or string and stakes
-  clipboard and pen

Procedure

If you are part of a class, work in teams of 3–4 students for this activity. Use the graphing area to record your data.

1. At your research area, identify dandelion plants by the distinctive yellow flowers, the iconic seed heads that blow into the wind, and the jagged leaves centered around each plant.
2. Measure the area of the entire study site in square meters.
3. Before sampling, visually estimate the population size of dandelions.
4. Measure out and mark the belt transect sampling areas as directed by your instructor (one transect of 3 m × 10 m per group).



5. Pick three spots to randomly sample by closing your eyes and tossing the hula hoop into different areas of your transect.
6. After each toss, record the exact number of dandelion plants within each circular plot. Be sure to count dandelion leaves emanating from one spot as one plant.
7. Play with the hula hoop. This will not help you estimate the total population size, but it will be fun.

— Data and Graph —

Data Analysis

1. Measure the diameter of your hula hoop, and then calculate the area of your circular plot in m^2 using the area of a circle formula πr^2 .
2. Calculate the mean number of dandelions per circular plot between the three tosses in your belt transect.

- Determine the expected mean number of dandelions per square meter. To do this, calculate the ratio of the mean number of dandelions per circular plot to the area of your circular plot. Then solve for the expected mean number per square meter. For example:

$$\frac{12.5 \frac{\text{dandelions}}{\text{plot}}}{0.822 \frac{\text{m}^2}{\text{plot}}} = X$$

$$X = 15.2 \frac{\text{dandelions}}{\text{m}^2}$$

- Calculate the total number of dandelions in the entire study area by multiplying your estimate of dandelion abundance in square meters by the total area of the study site.
- Draw a bar chart with vertical bars representing all fields of various sizes on your school campus. The chart illustrates the number of dandelions expected in a site (y -axis) versus site area (x -axis). Using this method, can you generate a rough estimate of the entire population of dandelions at your school?



Simple and fresh and fair from winter's close emerging,
As if no artifice of fashion, business, politics, had ever been,
Forth from its sunny nook of shelter'd grass—innocent,
golden, calm as the dawn,
The spring's first dandelion shows its trustful face.

—Walt Whitman, "The First Dandelion" (1888)

— Commonplace Space —



QUESTIONS

1. Compare your original estimate with your random sampling estimate. Which is larger? Which estimate do you think more realistically approximates the actual population size?

2. Does dandelion density vary between transects within the study site? If so, what might account for these differences?

3. Draw a dandelion in the sketch area provided, including the leaf and flower structure.

— Sketch —

Activity 2

Backyard Biodiversity

Today's Date _____

General Information

Environmental Science text reference: Chapter 1

Estimated time: 30 minutes to become proficient with Seek app; 1–2 hours per survey (2 surveys)

Activity type: field data methods

Introduction

Do you know what kinds of insects are flying around your yard on a warm summer evening? Have you ever noticed how many different birds visit backyard feeders in the winter? What types of fish can you catch in the nearest lake or river? These are all questions of biodiversity: a measure of how many species are present in a given area at a given time.

In order to answer these kinds of questions, field biologists have been recording observations, collecting specimens, and publishing their findings for centuries. However, in just the last few decades, amateur citizen scientists and students have also made significant contributions to our knowledge of local and global biodiversity.

One important task of an environmental scientist is the collection of baseline biodiversity data in a given study area. With initial species-richness values for comparison at the beginning of a study, it is possible to determine whether biodiversity is decreasing, increasing, or holding steady.

Near the beginning of the school year, initiate your own biodiversity study with an introductory survey that establishes some baseline data from your backyard or a similar area near your home. You can follow up with 2–3 seasonal surveys (fall, winter, spring) to investigate the flora and fauna present during those times of the year.

In order to get help identifying plants, insects, and other organisms, download the free Seek app on your smartphone or tablet. Using your device's camera, the Seek app identifies the organism as it comes into focus, and it has a fairly good success rate. If you do not have access to a device or a camera, search for compact field guides to birds, mammals, reptiles, insects, etc. that can be checked out of a library.

Objectives

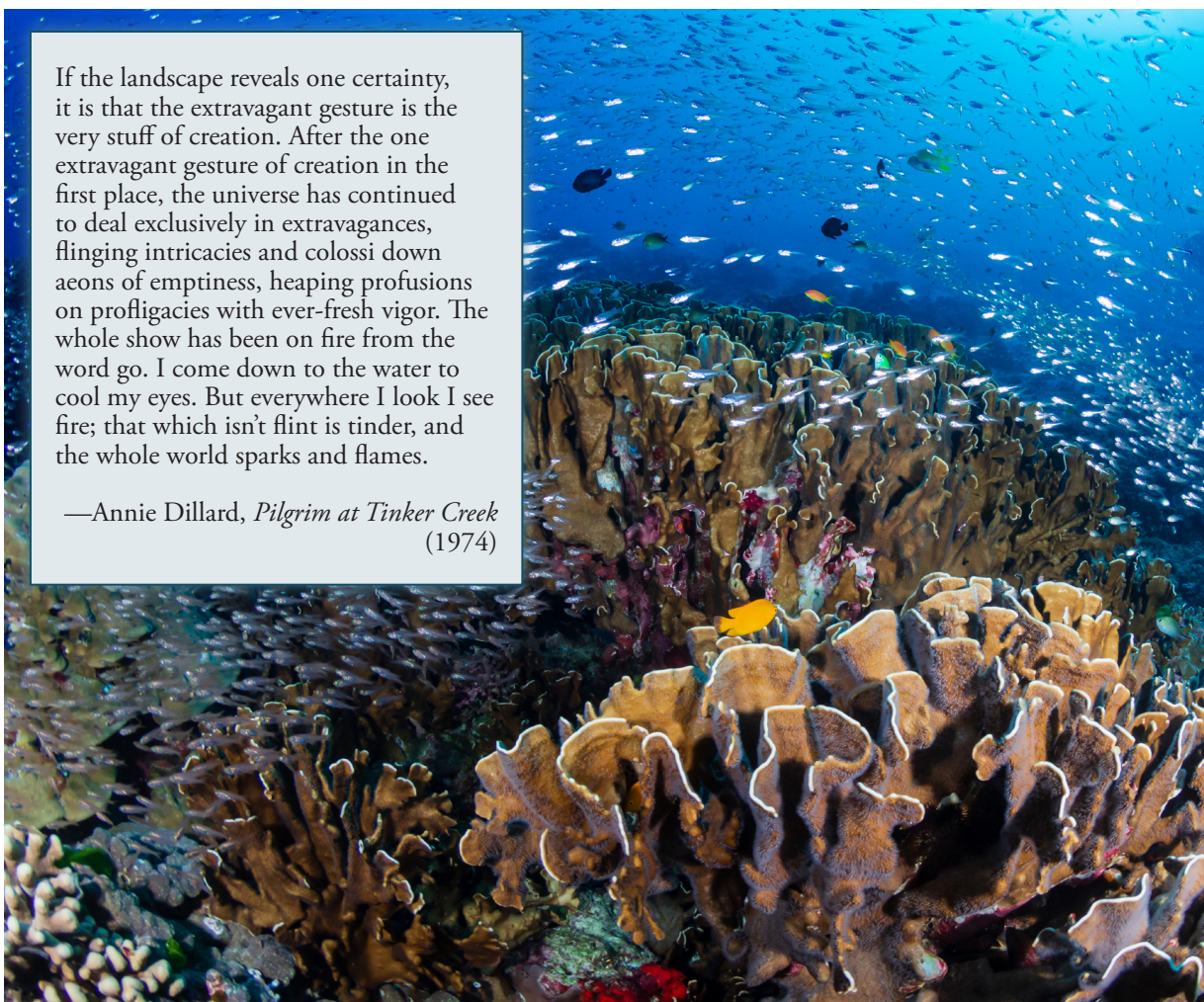
-  Investigate the biodiversity of local flora and fauna through a baseline survey.
-  Conduct two seasonal backyard biodiversity surveys during the school year.
-  Practice photographing and sketching plants and insects in the field.
-  Synthesize observational data and create presentations comparing surveys.

Materials (per student)

-  smartphone or tablet to run Seek app
-  camera (if no device camera is available)
-  field guides for local birds, reptiles, mammals, insects, etc.

If the landscape reveals one certainty, it is that the extravagant gesture is the very stuff of creation. After the one extravagant gesture of creation in the first place, the universe has continued to deal exclusively in extravagances, flinging intricacies and colossi down aeons of emptiness, heaping profusions on profligacies with ever-fresh vigor. The whole show has been on fire from the word go. I come down to the water to cool my eyes. But everywhere I look I see fire; that which isn't flint is tinder, and the whole world sparks and flames.

—Annie Dillard, *Pilgrim at Tinker Creek* (1974)



Procedure

Work individually for this activity.

1. Download the “Seek” app to your smartphone or tablet.
2. To become familiar with the app, open “Seek” and photograph 10 species of plants and 10 species of insects found in your yard or school grounds during the course of this week. These photos will be used for your baseline biodiversity survey.
3. Upload your photos from your device to a computer or email the photos to yourself.
4. If you observed animal tracks or just couldn't get a photo of that hawk flying over, search online for photographs (with citations) you can include in your slide presentation.
5. For most temperate zone biomes, plan your surveys during the following months for each season:
 - Summer (baseline—survey #1): August–September
 - Fall/Winter (survey #2): October–February
 - Spring/Summer (survey #3): March–June
6. Create a short slide presentation in Powerpoint, Google Slides, Keynote, or other software.

7. Presentations should include at least five slides: (1) title slide, (2) yard description slide with photos, (3) species list, including screenshots from the Seek app, 4) slide connecting your species in a food web (who eats who), and (5) works cited slide if you referenced field guides or used others' photography in your presentation.
8. You do not have to create a new presentation for each seasonal survey. Create one slide show for your initial baseline survey, and then add to it after successive surveys, being careful to label slides as baseline, fall/winter, spring/summer, etc. After you have completed your final survey in the spring, add summary slides to your presentation pointing out seasonal differences you detected between surveys, as well as some interesting learning experiences you had while conducting this research.

— Commonplace Space —

You may wish to peruse the poetry about plants in the New Shoots Poetry Anthology produced by Red Room Poetry

- (<https://redroompoetry.org/projects/new-shoots-garden-of-poems/>).
- Ian Gibbons' poem "Sensurrious" includes a link to a four-minute video of his poem with beautiful artwork that you can watch on Vimeo.
- <https://vimeo.com/189102859>



Questions

1. Were there any plants or animals that surprised you when you discovered they were present in your own backyard?

2. Did you notice any seasonal differences between the surveys, or were the same species present each time? In your answer, propose a hypothesis as to why you did or did not observe seasonality in your study area.

3. Pick one plant species and one insect species you recorded during your surveys and practice your scientific illustration by carefully sketching them in the sketch area. Use photographs you took in the field as a guide.

— Sketches —