Using Data-Collection Activities to Enrich Science Courses

Richard Grumbine

Abstract

I describe the use of long-term data-collection projects for introductory biology or environmental science students at both the high school and the college nonmajors level. I provide specific examples of projects and information on guiding students as they learn to gather, organize, and describe data sets.

Key Words: Data collection; inquiry; student research; science process skills; ecology.

When I was a child, around 10 years old, I pored over the annual publication World Almanac and tried to make meaning of the world through banks of data I found interesting, primarily information about sports and US presidents. I would skim the almanac for something interesting and then copy or reformat the data on either notebook or graph paper. By doing this, I began to make meaning of the data set: what was the maximum, what was the range, what was the average over the years? For a reason we scientists all understand better now, this past-time gave me great pleasure. I still like data: sports statistics, music statistics, and various science-related data. I guess I like looking for patterns. Now that I teach science, I also see the value in having my students gather and analyze data.

Part of the inquiry-learning model emphasizes course activities that involve collecting, organizing, and interpreting scientific data. Both the Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993) and the National Science Education Standards (National Research Council, 1996) call on teachers to design courses so that students learn science by doing science: posing relevant, testable questions; designing appropriate protocols for investigating these questions; and assembling and deciphering the results of the investigations. In this way, educators promote the scientific literacy of all students. Some have argued that inquiry activities are aligned with how learners construct deep and lasting meaning from their educational experiences (Tobin et al., 1994; Bransford et al., 2000).

Here, I describe and summarize inquiry-based ecological activities that emphasize long-term data gathering. These exercises are appropriate for either high school or nonmajor college students. By long-term data, I mean data that are collected over several semesters, terms, or years, by different students in different courses. Although each data-gathering project includes other essential aspects of inquiry learning, such as forming hypotheses, developing experimental designs, and communicating findings, I focus here on the data-related components of the activities, in the hope that science instructors might develop their own projects that emphasize long-term data collection over many semesters, terms, or years.

The Value of Long-Term Data Collection

Long-term data collection is critical to the scientific understanding of many ecological systems and provides insights into local and global environmental changes. Scientists are increasingly developing collaborative networks to gather and share long-term data that further scientific research. Efforts such as the National Science Foundation’s Long Term Ecological Research Network (http://www.lternet.edu/) have enabled scientists to intensively track changes in 26 varied ecosystems across the United States (Hobbie, 2003). The US Geological Survey’s North American Breeding Bird Survey (http://www.pwrc.usgs.gov/BBS/index.html) has tracked bird populations since 1966 and has significantly contributed to our understanding of bird conservation (Valiela & Martinetto, 2007). Some long-term data-collection efforts involve “citizen scientists” – trained volunteer data collectors (including students) who assist scientists in gathering data. Some examples are the Community Collaborative Rain, Snow and Hail Network (http://www.cocorahs.org); the World Water Monitoring Day program (http://www.worldwatermonitoringday.org); the GLOBE Program (http://www.globe.gov/); and various projects sponsored by the Cornell Laboratory of Ornithology (e.g., the search for the Ivory-billed Woodpecker; http://www.birds.cornell.edu/ivory/). Such efforts provide meaningful information that can lead to scientific insights at many scales.

Data & Inquiry Skills

Various state science standards either lump together or divide data-based inquiry skills (Illinois State Board of Education, 1997; Vermont Department of Education, 2010). In an attempt to better classify the skills involved in working with data from inquiry-based activities – long-term or short-term – I propose the following breakdown: gathering data, organizing data, and describing data.

The American Biology Teacher, Vol. 72, No. 6, pages 369–372. ISSN 0002-7685, electronic ISSN 1938–4211. ©2010 by National Association of Biology Teachers. All rights reserved. Request permission to photocopy or reproduce article content at the University of California Press’s Rights and Permissions Web site at www.ucpressjournals.com/reprintinfo.asp. DOI: 10.1525/abt.2010.72.6.11
Gathering Data

To gather data effectively, students need to understand and be able to apply a proper protocol, either teacher-designed or student-designed. This should include frequency of collection, sequencing of collection, and mastery of collection techniques. In the long-term data-gathering activities described here, the specific students who collect data will change, yet the protocols must remain essentially the same for the data set to be valid. However, because the emphasis of these activities is educational and they are not directed toward publication of results, the instructor has some flexibility in adhering to rigid protocols over time.

To maximize success and ensure the integrity of the data, the students will need training and practice in all protocols, including devising an adequate data-recording system. In all of the examples that follow, data-collecting practice or training is embedded within each activity to maximize student success and data quality.

Organizing Data

After a set of raw data is collected, the students perform various calculations and conversions to organize the data into a more useful format. One of the values of engaging students in long-term data-collecting activities is that a range of different organizing activities can be completed, giving them experience with a variety of tasks. The students learn to see the value of compiling, organizing, and converting data as a way to reveal trends and patterns – in short, to distill meaning from numbers.

The organizing tasks can be relatively simple, such as determining averages or percentages. These are considered basic or descriptive statistical tasks. The goal is simply to condense many data points into a meaningful and manageable form. Once this is done, it is possible to determine additional calculations such as correlations, standard deviations, or t-tests using software. These kinds of tests are considered inferential statistical tasks: their purpose is to help students generalize or make inferences about the data.

All data-organizing exercises can be presented in either tables or graphs, which provide another important learning opportunity for students. Learning how to construct and refine tables using Microsoft Word or generate graphs using Microsoft Excel (or similar software), or by hand, is essential for most students to grasp the meaning of their data-collecting activities. This can take additional instructional time (particularly with Excel), and there can be a steep learning curve for students who are unfamiliar with the software being used. I provide a graph-making “tutorial” handout for students when I deem it essential for them to master this skill. I also give them examples of good (but simple) graphs and examples of data-entry guidelines. This helps them visualize the end product they are striving for.

Describing Data

When I was a child, sorting through and then representing data in more organized forms, my ultimate goal was to make meaning of this information and discover patterns. This step is the next and crucial task for science students as they work with long-term data. This can be difficult work for some students, it requires that they notice and describe the most salient features of a table or graph. Providing guiding questions orally and in writing may be helpful to support students as they practice and acquire this skill. “What aspect of the graph or table is most prominent?” and “What are the lowest and highest values in the graph or table?” are two basic examples of guiding questions. Students often need specific guiding prompts to successfully perform higher-level tasks such as noting data trends over time or across categories (e.g., “Do the bars in the graph go up and down in a pattern?” and “Do the bars steadily get taller or smaller?”) and comparing and contrasting specific aspects of the data (e.g., “Are the data for site 1 similar to or different from the data for site 2?”).

Examples of Activities

Here are a few examples of long-term data-collecting activities that I use with my students. I have found that all these activities effectively improve the data skills of freshman and sophomore college students in the introductory biology and environmental courses I teach.

Comparing Ecosystems

In this investigation, students have been collecting data for several years on two prominent ecosystems that are easily accessible to our classroom: the lawn and the deciduous forest. Their overarching objective is to explore how several physical and biological variables differ in these ecosystems.

Figure 1. Sample graph from the Comparing Ecosystems activity.
Table 1. Sample of red-backed salamander data.

<table>
<thead>
<tr>
<th>Semester &amp; Date of Collection</th>
<th>Number of Salamanders Found</th>
<th>Number of Boards Checked</th>
<th>Percentage of Boards with Salamanders</th>
<th>Board Numbers</th>
<th>Soil pH</th>
<th>Percent Soil Moisture</th>
<th>Soil Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 5 4/23/07</td>
<td>2</td>
<td>27</td>
<td>7</td>
<td>14, 17</td>
<td>5</td>
<td>22</td>
<td>9</td>
</tr>
<tr>
<td>Site 5 10/01/07</td>
<td>3</td>
<td>24</td>
<td>8</td>
<td>4, 13 (2−)</td>
<td>5.5</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>Site 5 4/22/08</td>
<td>1</td>
<td>20</td>
<td>5</td>
<td>13</td>
<td>4.25</td>
<td>20</td>
<td>10.5</td>
</tr>
<tr>
<td>Site 5 9/30/08</td>
<td>14</td>
<td>25</td>
<td>56</td>
<td>1, 2, 4, 5, 12, 16, 17, 24, 26</td>
<td>6</td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td>Site 5 10/16/08</td>
<td>9</td>
<td>25</td>
<td>36</td>
<td>2, 3, 5, 8, 16, 17, 26</td>
<td>5.5</td>
<td>20</td>
<td>13</td>
</tr>
</tbody>
</table>

Table 2. Example of water quality data (E. coli colonies per 100 mL water).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Site B</td>
<td>155</td>
<td>270</td>
<td>3</td>
<td>58</td>
<td>394</td>
</tr>
<tr>
<td>Site C</td>
<td>76</td>
<td>100</td>
<td>12</td>
<td>25</td>
<td>16</td>
</tr>
<tr>
<td>Site D</td>
<td>10</td>
<td>37</td>
<td>5</td>
<td>17</td>
<td>4</td>
</tr>
<tr>
<td>Site E</td>
<td>14</td>
<td>28</td>
<td>3</td>
<td>38</td>
<td>8</td>
</tr>
<tr>
<td>Site F</td>
<td>38</td>
<td>62</td>
<td>2</td>
<td>22</td>
<td>28</td>
</tr>
</tbody>
</table>

geographically adjacent ecosystems. Each fall and spring semester, using some relatively simple techniques and basic monitoring devices, student teams gather data on air temperature, soil temperature, relative humidity, plant diversity, ground arthropod diversity, soil nitrogen, soil pH, and soil moisture. After being trained to use the equipment and proper methodologies for each testing variable, teams visit defined plots (which vary in precise location over time) in each of the two ecosystems during the same class period to collect their data.

After basic comparing and contrasting of the current data, the students are given access to the previously collected data. Their task is to merge the data into a composite table and describe the trends shown over time. They are also asked to generate a graph that compares one variable over time for each ecosystem (Figure 1).

Each class collects only one data set, but over time students have collected multiple “snapshots” of the environmental and biological variables sampled. A finite amount of course time can be devoted to this investigation each semester, yet the long-term data bank allows for a more meaningful and robust analysis of the ecosystems.

**Red-backed Salamanders**

In this investigation, students have been collecting data for 3 years on the local population of red-backed salamander (*Plethodon cinerus*) using artificial cover objects (ACOs). The protocol for this investigation was developed using the work of the US Geological Survey Patuxent Wildlife Research Center and that of Tomasek et al. (2005) of the University of North Carolina, Greensboro.

The overall objective is to monitor the resident population of red-backed salamanders and determine environmental and habitat preferences. Ultimately, some indication of larger population trends may be revealed. Student groups are trained in the relatively simple protocols, which include carefully checking the arrays of plywood ACOs for red-backed salamanders and measuring soil moisture, soil pH, and soil temperature in several plots in the surrounding campus forest. One or two sets of data are collected in both fall (late September–early October) and spring (late April–early May) semesters.

As in the “Comparing Ecosystems” investigation, the students begin their data analysis by organizing and describing the data they have recently collected. All the previously collected data from past semesters are then distributed to them, and they are responsible for making a composite table of all data (Table 1). They are assigned to generate a graph (or graphs) showing the population trends over time plotted against the environmental conditions, in an attempt to identify possible correlations or patterns in the entire data set. This can be a challenging task and often raises good insights and questions from the students. They might, for example, notice that certain cover boards frequently have salamanders under them. They then wonder if the same individual salamander is found each time and if the salamanders are territorial.

**Water Quality**

In this investigation, students test the water quality and assess the ecological health of a local stream. Over the more than 10 years that I have been facilitating this investigation, students have monitored the same three sampling sites about once a year. The primary objective is to determine which of the three sampling sites has the best water quality as measured by various physical, chemical, and biological parameters.

Although the sampling entails collecting data on various parameters of stream health, I will focus here on data collection pertaining to *Escherichia coli*. In addition to collecting *E. coli* from the main three sampling sites tested for the various other parameters, the students also sample local swimming holes and other significant sites in the vicinity of the school. These sites become part of the long-term collection of stream data for *E. coli*. The field data-collection protocols for this investigation are relatively simple, but the laboratory protocols are more involved. There are several *E. coli* sampling protocols in the literature; I use the Environmental Protection Agency–certified membrane-filtration laboratory method using Hach’s m-Coli blue media (Crane et al., 2006). After the students are trained in the data-collection and laboratory procedures, they learn how to count bacterial colonies.

As in the other example activities, the students begin their data analysis by organizing and describing the *E. coli* data they have collected. Once they are able to make some basic comparisons between the sites, I distribute *E. coli* data from past semesters (Table 2). They are asked to reorganize the data into one or more graphs that show the *E. coli* patterns...
at each site over the years of sampling. They then attempt to describe the overall trends and insights contained in the entire data set.

**Conclusion**

Giving students the opportunity to collect, transform, and describe data as part of long-term scientific investigations promotes many positive outcomes. It gives students a chance to experience the breadth and complexity of real-world data; they feel they are participating in real science, and they see that their data add to the collective body of knowledge that future students will evaluate. It allows them to practice developing the necessary skills to uncover long-term trends or patterns that one-time-only data collection does not allow. It gives them a sense of connection to the local environment around the school. And finally, these activities are engaging, fun, and motivating for students (and their instructors!).

**Acknowledgments**

I thank the following colleagues for their feedback and support: J. Bruce Lord, Kim Coleman, and Meg Baronian. I am also grateful to the anonymous reviewers of the original manuscript.

**References**


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