Worms Cultivate Our Curriculum:
A Long-Term, Theme-Based Unit

Claudia T. Melear and Eddie Lunsford

Abstract. This article provides basic information on how a common species of earthworm, *Eisenia fetida*, can be used in the biology classroom as well as a discussion of how to establish and care for a vermicompost bin. We discuss ideas for inquiry activities with the organism and provide a sample-guided inquiry that demonstrates how a long-term, theme-based unit involving earthworms can address a wide variety of content from the National Science Education standards.

Keywords: authentic science, composting, earthworm, inquiry, integrated curriculum

In the United States, emphasis is placed on inquiry-based activities in the classrooms (National Research Council 1996; 2000). The primary argument for doing this is so students will be more likely to understand the process skills of science. These are the methods by which scientists operate when they are "on the job" (Enger and Yager 1998). The National Science Education (NSE) standards can be daunting to teachers at any level of education; "How can I cover all of this?" is a common immediate reaction by most teachers who see the standards for the first time. In this article, we summarize our efforts to use a common organism, the earthworm, in inquiry and theme-driven lessons that efficiently address multiple standards. Ignatz (2005) recently considered theme-driven lessons as a means to integrate content across disciplines for preservice teachers. Our primary goal was to demonstrate that simple activities, with earthworms as a unifying theme, can provide deep and meaningful experiences that simultaneously address a number of NSE standards. In other words, we are not merely describing a single activity that takes place during one or two class periods. In an effort to help teachers and their students get started, we supply a sample inquiry lesson in appendix A. Students should be encouraged to formulate their own research questions, hypotheses, and methods and to explore topics that are of interest to them (National Research Council 2000).

Why Earthworms? A Perspective

> Finally, no one who considers the facts given in this chapter . . . on the vast number of worms which live within a moderate extent of ground on the weight of the castings ejected from the mouth of the same burrow—on the weight of all the castings ejected within a known time on a measured space—will hereafter, as I believe, doubt that worms play an important part in nature. (Darwin 1881, 37)

Historical records indicate that English naturalist Charles Darwin was probably the first person to conduct and publish a long-term investigation of earthworms. Darwin examined how they feed and how they process and distribute their feces. By distributing their feces, called *castings*, earthworms aerate the soil and ensure that a number of biogeochemical cycles continue through the ages (Gajalakshmi, Ganesh, and Abbasi 2005).

Mary Appelhof, a modern champion of earthworms, published *Worms Eat My Garbage: How to Set Up and Maintain a Worm Composting System*. In the second edition (1997), Appelhof details how vermicomposting systems can be constructed and maintained. She currently runs a Web site that can be a valuable reference for teachers (see http://www.wormwoman.com).

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Maintaining an Earthworm Culture

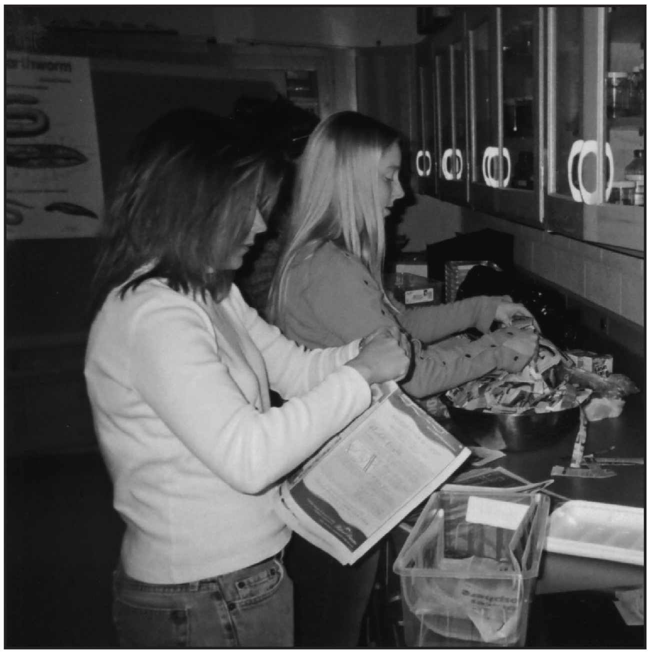
It is important to know that not just any species of earthworm is suitable for keeping in culture. Several species are good candidates, but the organism of choice is *Eisenia fetida*. This particular species is an epigeic organism, meaning that it may be most commonly found living and feeding among leaf litter. Some naturalized populations of *E. fetida* exist (Appelhof 1997; Gajalakshmi, Ganesh, and Abbasi 2005), but it is most easily obtained from bait shops, nursery catalogs, and vermicomposting suppliers. The size of the container in which worms are kept depends on the vermicomposter's goal. Commercially prepared containers are available.

A suitable environment can be produced with damp, shredded newspapers, ample (but not excessive) moisture, and addition of foods. *E. fetida* will consume a wide variety of foods, from kitchen scraps to its newspaper bedding. Keeping a vermicomposting bin in the classroom is easy. It requires very little maintenance, although the vermicomposter should remove castings, add food, and change bedding regularly. Castings may be used to topdress houseplants and may even lead to student-generated inquiries involving comparing various soil types.

The earthworms require little intensive care: they thrive in dark conditions and at temperatures ranging from 15°C to 25°C. Although they require a moist environment, earthworms can die in standing water. Further, they seek out dark conditions. Mold in a new compost bin, or in a bin with newly added food, is not only expected, but a good sign that food materials are actively decomposing. Strong odors almost always indicate overfeeding. Other organisms such as fruit flies, mites, and roundworms routinely find their way into healthy vermicomposting bins (Appelhof 1997). Students and teachers should be reminded that keeping live animals in the classroom and using them in inquiry lessons comes with responsibility. For example, no harm should be intentionally brought to the organisms (NSTA 2005). Table 1 lists a number of variables affecting the vermicomposting results.

Using Earthworms in Your Teaching

We have taught high-school level biology courses in the past and currently instruct undergraduate and graduate students preparing for teaching positions. In our current college classrooms, we have successfully used earthworms and composting in varied ways. Activities with vermicomposting have centered on observation of established culture bins, setting up new bins linking observations to other topics studied in class, and carrying out long-term inquiry activities with *E. fetida*. Appendix B provides a list of suggested materials with which to begin long-term observation and inquiry activities in your classroom. Fig-



Students tear strips of newspaper to prepare bedding materials.

Table 1. Variables That Affect the Vermicomposting Experiment

Independent	Dependent
Natural versus manmade foods	Increase in length and diameter of worms
Length of photoperiod	Mass or volume of castings produced
Short exposure to bright light	Volume or mass of food remaining
Temperature of environment	Survival instinct of worms
Presence of predator	Feeding behavior of predator to indicate release of toxin by worm
Various types of foods	Number of cocoons or juvenile worms to indicate reproductive success
Presence of worms in planting container	Germination or growth or seeds and plants
Moisture content of bin	Positive or negative toxic responses
Various bedding materials	Presence of clitellum to indicate sexual maturity
Mechanical stimulation	

ure 1 provides a summary of how our various activities relate to the NSE standards. We further discuss examples of our assorted classroom activities in this article.

Science Content Standards

NSE standards are designed to help students and teachers identify content knowledge and skills that a successful student should master (National Research Council 1996). Specific standards addressed by our use of earthworms include unifying concepts and processes, science as inquiry, personal and social perspectives, history and nature of science, and content related to physical science, biology, and earth science.

Unifying Concepts and Processes in Science

Vermicomposting bins may serve as tangible foundations from which to teach and illustrate biogeochemical cycles operating in nature. Aspects of the nitrogen, carbon, and water cycles can be easily incorporated into the theme of this activity. It should be noted that various minerals, such as phosphorous and potassium, are at least partially cycled by earthworms as well. Learners may also consider how *E. fetida* has adapted to epigeic environments by observing earthworm behavior and considering photoreceptors, protective mucous, and setae. Within the meaningful context of inquiry, students may practice measurement skills by determining the masses or volumes of such variables as (a) food added to the culture, (b) castings produced by the culture, (c) amount of moisture, and (d) earthworm growth or reproductive rates over time.

Science as Inquiry Standards

One of our most widely used activities allows students to design and carry out long-term investigations using *E. fetida* and formulate their own research questions. Appendix C lists examples of actual inquiries carried out by our students. As these inquiry activities get under way, students and teachers present and discuss the scientific evidence from their work and draw conclusions.

Physical Science, Life Science, and Earth and Space Science Standards

Well-planned lessons involving composting and earthworms provide a powerful means to address a wide variety of content. For example, students may observe and quantify changes in food materials and castings within the compost

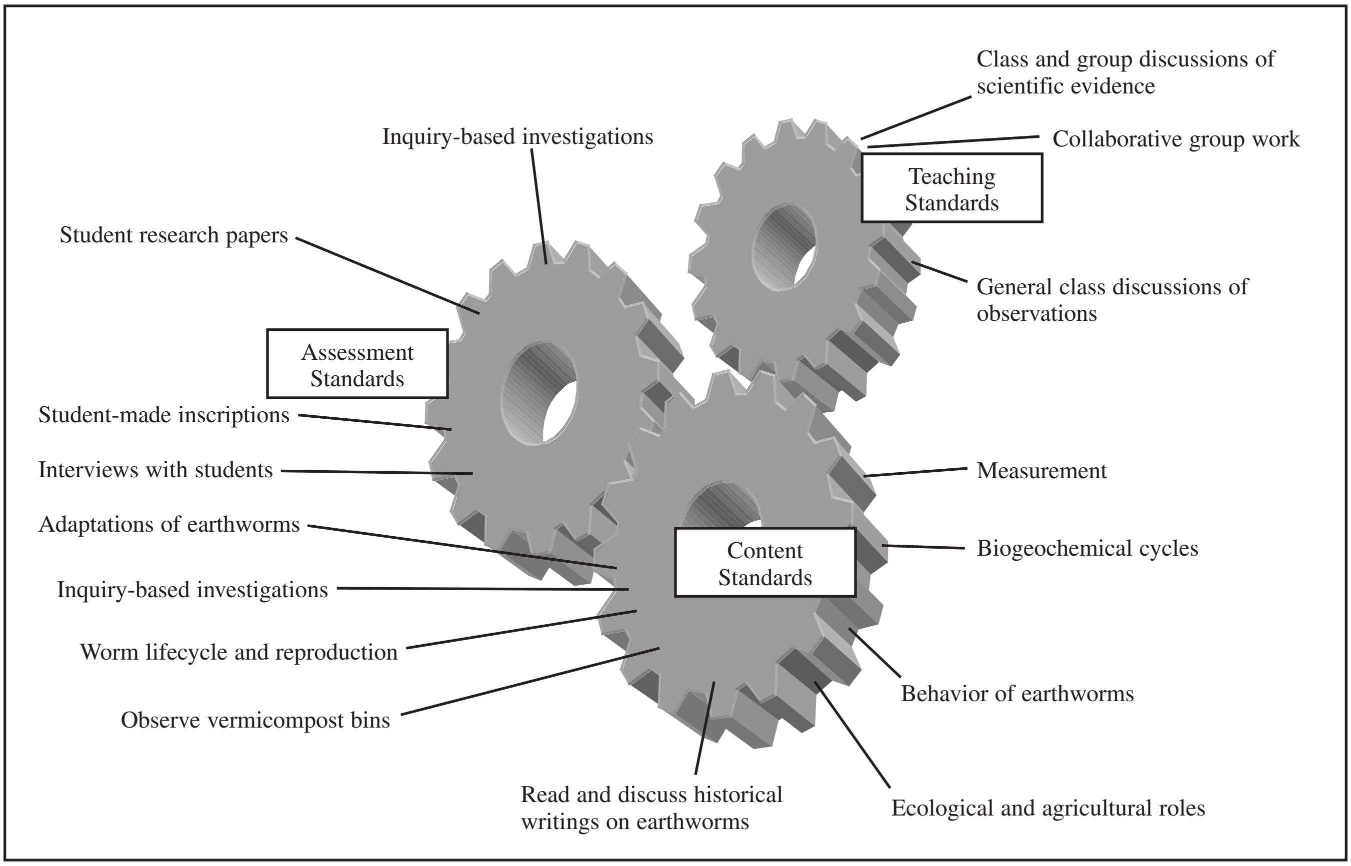


FIGURE 1. Earthworms and the National Science Education (NSE) standards.

Students prepare food for their earthworm inquiry.

bin. Also, they can study the worm's life cycle by observing cocoons, reproductive activities, and growth rates of juvenile *E. fetida*. Behavioral responses of the worms to various environmental variables, such as light and moisture, are readily observed. Finally, students may consider the ecological roles of *E. fetida*, along with various other organisms that are invariably found in vermicompost systems. As previously noted, all of this can be linked with various biogeochemical cycles.

Science in Personal and Social Perspectives Standards

Members of the learning community may consider, or actually apply, the uses of compost and castings in nature and in gardening or agriculture. Also, they may manipulate various environmental variables and track population changes of *E. fetida* in these circumstances.

History and Nature of Science Standards

Darwin's (1881) monograph on earthworms is an ideal choice for reading about science from a historical perspective. Well over a century after his death, Darwin's writing style is still very understandable and his observations are incredibly accurate. Also, to help achieve this set of standards, students can consider evidence from the observations and inquiries they and others have carried out. These discussions help students to evaluate their hypotheses and conclusions.

Students search for worm cocoons in castings.

Assessment Standards in Science Education

The assessment standards have implications for all levels of education (National Research Council 1996). Because learning activities are so closely tied to tangible experiences, the lessons we describe offer many authentic assessment opportunities. Teachers may assess the ability of their students to carry out inquiry by actually having them perform one or more guided or open inquiries with earthworms. Final graded assignments may include research papers on the inquiry, student-made inscriptions, or other various types of evidence of mastery.

In figure 2, the student-made inscription could be improved by more careful labeling of the axes. Teacher or peer evaluation could help in this endeavor. If a student writes, speaks, or otherwise communicates about the work they have completed with vermicomposting, then the assessment is highly valid and genuine. Teachers may perform formative or summative assessments with students in the form of an interview. Appendix C provides excerpts from such an interview. In this example, the student had not yet observed or worked with a vermicompost system. The questions could serve as advance organizers to help students get the most out of the activity. Such interviews can also enlighten teachers regarding their students' understandings of science content.

Teaching Standards in Science Education

Overlapping assessment and content goals, the teaching standards help define the role of educators in the science

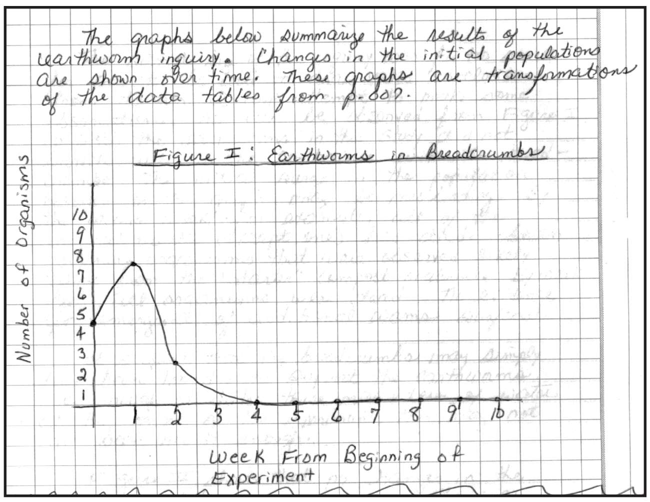


FIGURE 2. A sample graph illustrating changes in the initial populations of earthworms over time.

classroom and beyond (National Research Council 1996). A few examples of how inquiry-based and thematic centered activities with *E. fetida* may help attain the teaching standards are considered below.

In regard to vermicomposting and earthworms, we see ourselves as facilitators. For activities such as these, we provided the raw materials and helped students hone their scientific questions and methods and evaluate their conclusions. Frequent discussions among the entire class or among individual work groups are one way to do this. Allowing students to maintain laboratory inscription notebooks or make reflective journal entries concerning their progress are other ways teachers can facilitate learning.

Well-planned and effective assessment methods are critical to theme-based lessons. In addition to the assessments already discussed, teachers may also provide checklists or scoring rubrics to help students to monitor their own progress toward mastery (Lunsford and Melear 2004).

Laboratory activities such as the ones described in this article do not necessarily have to be artificially separated from traditional classroom activities. In fact, they can provide a springboard for lecture and discussion. We also recommend frequent, shorter laboratory sessions so that students can give their attention to their ongoing observations and inquiries. Devoting even a few minutes of each class or lab period to discussion, observation, writing, and other activities linked with the earthworms can make for a more meaningful and more connected experience for the student.

Finally, we seek to foster a sense of community among members of the classroom as they experience and learn science content. Periodically, small group discussions naturally give way to entire class discussions. Students can come up with their own inquiry questions and help others to hone those questions. Teachers may model appropriate scientific discourse by asking questions about student procedures, sample sizes, replication, evidence, and conclusions. With practice, the entire class becomes a collaborative, scientific learning community.

Summary and Discussion

Inquiry-based and theme-driven lessons can be used to master the NSE standards. Although we have used *E. fetida* and vermicomposting bins with great success, these are not the only choices. A wide variety of organisms, models, and learning opportunities exist as options. Students can base their learning on organisms living in terrariums and aquariums, mealworms, fast-growing plants, or even bacterial cultures. Connecting learning is a shared authentic experience that creates a more meaningful experience for students. Teachers will teach as they have been taught. Engaging preservice science teachers in activities such as these will, hopefully, help them better serve their future students.

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Appendix A
Sample Guided Inquiry Classroom Activity: Observing Earthworms in Vermicomposting Bins

Question: Will *Eisenia fetida* process food into vermicompost more quickly in a dark environment?

Materials:
- Established vermicompost bin
- Sandwich-sized plastic containers (approximately 15 × 15 cm) with lids; use at least four containers per team of students
- Old newspapers (avoid colored ink)
- Dissection needle or straight pin
- Tap water
- Scale
- Desk lamps with timers (optional)
- Drawer or box
- Apples, grapes, or other small pieces of fruit
- Sharp knife or scalpel
- Plastic spoon or small beaker

Procedure:
1. Divide into groups consisting of three to four students each.
2. Line the bottoms of four containers with a layer of newspaper. Place shredded newspaper that has been soaked in water and drained on top of the lining. This will serve as bedding material for the earthworms. Bedding should be moist but not dripping with water. Use a scale to ensure that equal masses of bedding are placed in all containers.
3. Use a dissection needle or straight pin to pierce four air holes, equally spaced, in all container lids.
4. Use a scale to measure an equal mass of food for each container. About 10 to 12 g of food will be sufficient. Cut food into small cubes of approximately equal size. Note the precise mass of food added to the containers.
5. Bury the food in the bedding material in each container and add six adult worms. From the primary compost bin, remove some compost. Add approximately 1 tsp (about 5 ml) to each container. This compost contains a number of microorganisms and will serve as a starter for the new containers. Note the precise volume added to the containers.
6. Place lids tightly on all the containers. Mark two of the containers “control” and two containers “experimental.”
7. The two replicates of the experimental containers (see step 2) should be placed inside a box or drawer in which they will receive constant darkness away from extreme heat.
8. The two replicates of the control containers (see step 2) should be placed in a location, away from direct sun or extreme heat, in which they will receive daily exposure to roughly equal time periods of light and darkness. A fluorescent lamp, equipped with an automatic timer, may be used if the classroom is kept dark during weekends or holidays.
9. Open containers at the end of three weeks. Return worms to the primary compost bin.
10. Measure the mass of any remaining (unprocessed) food material present in each container. Alternatively, measure the volume of compost produced in each container.
11. Share the results of your inquiry with other class members. Class data, rather than individual team data, will increase the sample size and strengthen any conclusions that students may draw from the inquiry.

Evaluation and Extensions. Students can write a scientific research paper based on their laboratory findings for this sample-guided inquiry. Bar graphs comparing class data for the amount of food remaining or compost produced at the end of the activity, for example, may be included as well. Have that students select their own research questions and design their own experiments with *E. fetida* as an expansion of the activity.

Appendix B
Recommended Inquiry Starter Materials

The materials necessary to carry out an inquiry-based and theme-driven unit on earthworms and vermicomposting will vary according to your goals and objectives. Use the following list of materials as inquiry starters. Your students, particularly if you opt for an open-inquiry segment, may ask for other materials.

- **Primary compost bins:** In classrooms, these are the primary source of observation of worms.
- **Plastic containers with lids:** Students may use these to set up their own cultures or experiments. Container size may vary. Sandwich-sized containers (approximately 15 cm x 15 cm) represent a minimum size.
- **Dissection microscopes or hand lenses:** These aid in observing juvenile worms, cocoons, and other organisms.
- **Rulers and string:** Students can use these to measure worms.
- **Various food sources:** Fruit, bread, kitchen scraps, processed foods, or other various food material can be chosen. Worms also may feed on bedding material.

(appendix continues)

Appendix B (continued)

- **Newspaper:** This is used for worm bedding material. Tear the paper into long strips, soak the strips in water, and drain excess water. Black and white newsprint is safer for worms. Although the size of the strips is not significant, a good rule of thumb for size is approximately 4 cm x 30 cm. This size allows for easy handling of the strips and provides room for the earthworms to burrow inside. Also, food is easily buried in the strips.
- **Light source:** A small desk lamp, with or without a timer, allows students to examine behavioral responses of worms to light. Fluorescent lamps provide light without having to control for heat. When harvesting compost, heat and light may help distinguish worms from the castings.
- **Dark environment:** Keep cultures in an opaque container, a drawer, or cardboard box for constant darkness. A dark environment is important because earthworms are negatively phototaxic, meaning they try to avoid light. They will be less likely to try to escape from the container in a dark environment.
- **Plastic spoons:** Pick up and move worms safely using plastic spoons.
- **Gloves:** Some students may want to wear gloves while handling castings or worms. Nonlatex brands are the best option because students may have severe allergies to latex gloves.
- **Measurement devices:** Students may need thermometers, scales, graduated cylinders, beakers, flasks, or other such materials to quantify variables or experimental findings.
- **Paper and/or art supplies:** Students may need copy paper or drawing paper for recording inscriptions, graph paper, markers, pencils, paper, or tape for labeling containers, etc.
- **Various types of soil:** Students may want to compare germination or growth rates for seeds planted in worm castings versus potting soil, sand, clay, etc.
- **Other species of worms:** Students may want to compare *Eisenia fetida* with other species of earthworms in terms of their behavior, life cycle, or ability to produce compost.

Appendix C
Excerpt from Student Interview

Teacher (T): "Okay, well, now you said two things. You said something about roots getting nutrients from the soil. Then you said nutrients from photosynthesis. So is it both?"
Student (S): "Well, they get what they need from the soil like water and different organic materials in order to . . . like water, they need water in order to perform photosynthesis, and, um . . . I guess when you fertilize and stuff you can give them different organic nutrients that they need or inorganic nutrients."
T: "Which? Both?"
S: "Um, yeah, I would think it would be both because some plants need nitrogen and lime, different plants need different nutrients. Some need an acidic type of soil."
T: "What is the source of nitrogen?"
S: "Nitrogen?"
T: "For plants . . . where do plants get nitrogen?"
S: "That is a hard question. I am trying to think of all these little chemistry things; nitrogen. . ."
T: "Let me ask you, where do animals get nitrogen? What that we take in has nitrogen in it?"
S: "I know I know it, but I can't think of what it is . . ."
T: "I know you do too because you eat it every day. I mean, think of the compounds you eat every day. Think of categories of things, what are the categories of things you eat every day?"
S: "Like carbohydrates, lipids . . ."
T: "Yes, exactly. . . Now is there nitrogen in either of those?"
S: "All I can see is double bonds . . . carbon and hydrogen chains or something."
T: "Now, I am asking you, what is the source of nitrogen for a plant?"
S: "Source of nitrogen?"
T: "I guess I haven't established that yet. . . Although you said that they needed it, I think you mentioned it earlier that it was one of the minerals or the nutrients that is needed."
S: "Right, it would be in the soil, but are you asking how it got to the soil?"
T: "Yeah, what is the source of nitrogen in the soil if you are saying it comes from the soil?"
S: "I don't know."

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