VERMICULTURE:

Guided Inquiry Activities for the Study of Worms in the Classroom

By James Ealy, M. Ed

Edited by Julie B. Ealy, Ph. D.

Edited by Cary Oshins, M.S.

Produced by:

PROP PROFESSIONAL RECYCLERS OF PENNSYLVANIA

908 N 2nd Street
Harrisburg, PA 17102
www.proprecycles.org

Funded by:

pennsylvania DEPARTMENT OF ENVIRONMENTAL PROTECTION

Pennsylvania Department of Environmental Protection
https://www.dep.pa.gov/

VERMICULTURE:
Guided Inquiry Activities for the Study of Worms in the Classroom

By James Ealy, M. Ed, Edited by Julie B. Ealy, Ph. D. and Cary Oshins, M.S.

FORWARD

The Professional Recyclers of Pennsylvania (PROP) is pleased to present this set of lesson plans for the study of vermicomposting by middle and high school students. As a recycling association, we understand that educating our youth is one of the keys to a sustainable society. Elementary teachers have long used vermicomposting as a hook to teach the basics of organic recycling (composting) as well as key lessons in biology, ecology and math. To that end there are many excellent resources geared to the elementary classroom. However, recent changes in Pennsylvania Education Standards have made it clear that there was a critical lack in vermicomposting books targeted to the middle school level. Thanks to funding from the Pennsylvania Department of Environmental Protection for our professional development program, we went looking for someone to compile existing lessons in a compendium we could make available. Through a fortuitous turn of events Professor James Ealy of Cedar Crest College in Allentown, PA was not only willing to take on this task, but had the time and inclination to develop this set of original, inquiry-based activities. We hope that educators here in Pennsylvania, across the country, and indeed throughout the world will adopt and adapt the lessons for their classrooms. We also hope they will give us feedback on ways to improve and extend the lessons in the future.

INTRODUCTION

The middle school activities in this manual are based on an *inquiry approach* to teaching science. However, this is not a "turn them loose" approach. These activities require considerable coaching from a teacher's point of view. The activities require at least one home-made or commercial worm bin. The procedures for making a worm bin are contained in many of the items in the resources section.

The vermiculture (worm bin) should be started before or soon after school begins to provide the students with a visual concept. The first classes should be focused around this bin and students should be shown one or more of the videos listed in the reference section. Students should be required to search a library or do an Internet search. Several evaluated sites are listed in the reference section. After students have researched vermiculture and vermicomposting, presentations should be made by individuals or small groups. A successful *inquiry approach* to vermiculture uses small groups for research, study, and completing activities and presentations.

The activities in this manual can be used in the presented order or as stand-alone activities. These activities have information for the teacher and suggested directions for students – similar to generic lesson plans. The activities can be down loaded and then modified for a specific classroom approach. These activities have been linked to appropriate Pennsylvania Department of Education Standards: 8th grade math, 7th grade Science and Technology, and 7th grade Ecology. Not all possible standards are listed, only the major standards that can be easily demonstrated.

Getting Started

The instructor needs to be familiar with "red wiggler" worms, *Eisenia fetida* and their biology. This activity manual is not a reference for learning how to grow worms successfully in the classroom. Mary Appelhof's book, Worms Eat My Garbage, is more than suitable for this education. Most worm suppliers have basic techniques and concepts that will allow you to get started. There are a number of elementary teachers in Pennsylvania who have already used vermiculture for their science activities, as well as Internet discussion groups with a tremendous amount of information. Most of the information available as FAQs in the discussion groups is very reliable. The best pedagogy is to start at least one Habitat over the summer and profit from the experience. Students should not be asked to do any activity instructors have not completed several times. The only way to coach, guide, or direct an *inquiry approach* activity is to be very familiar with the activity and the mistakes that can be made or problems that can and will occur. Commercial worm bins are very easy to use and maintain, but they do cost money. However, having students design and build their own bins is a VERY worthwhile activity. The commercial bins are very easy to transport which may be necessary over the summer and school holidays.

Inquiry Approach

> "Inquiry is an approach to learning that involves a process of exploring the natural or material world, that leads to asking questions and making discoveries in the search for new understandings."
> https://www.exploratorium.edu/education/ifi/workshops/fundamentals/summary.

The activities in this manual are all inquiry-based. Many science and math methods instructors embrace an inquiry approach, but may not make it absolutely clear that an inquiry approach is **not** an **UNGUIDED** approach. The teacher must be both a coach and a co-inquirer, guiding the process of asking questions, investigating, data collecting, discussing and reflecting. Teachers who have engaged in graduate-level science research have experienced the inquiry approach with their advisors. These activities have been written for teachers with little or no science research background and include successful methodologies in the Strategy Section of each activity.

Student Participation

Science activities in the past were commonly completed as an individual or in pairs of students. The pairing of students was not a researched and proven method, but rather occurred to accommodate the lack of sufficient lab equipment. Teachers who have done graduate level science research understand that almost all research is accomplished in groups. In the business world groups are an integral part of marketing and sales, as well as research and design. Small groups work extremely well in K-12 laboratory classes. The number of students in a group has been hotly debated. We know from research that in K – 6, groups of 3 and 4 works successfully. At the 7 – 8 level, 2, 4 or even 5 can make a successful group. A group of three usually ends up with one student left out. We do know that cooperation and meaningful compromises are very important parts of every student's education. Having students work successfully in small groups provides a very relevant life experience.

Journals

This may be one of the most important aspects of these activities. Having students learn to always have their journal available, to record completely and correctly the data/results, to be able to use the journal in future activities and presentations, and to be a record of their work, are very important goals or objectives. The writing in the journal should be similar to a lab report that asks specific questions of the students and expects complete and well thought-out answers. Suggestions for journals are:

1. All observations, no matter how insignificant they may seem should be recorded.
2. Record dates, times, and conditions of the Habitat. BE ORGANIZED!
3. Explore further any observations that seem anomalous – out of character.
4. Write clearly and succinctly, so that others may read and understand.
5. Draw diagrams, pictures, and graphs.
6. Show any and all math involved.
7. Include ALL data, graphs, and charts.
8. Include any computer printouts of data, graphs, and charts.
9. Make comments on all data, graphs, and charts.
10. Make connections between the data, charts, graphs, and observations.
11. Include any notes from class or group discussions.
12. Include any teacher handouts.
13. Use them for presentations.

Presentations

In many cases these are the finishing touches applied to the work accomplished by the students. The following are three suggested types of presentations for middle school:

1. Spontaneous.
2. Planned by an individual.
3. Planned by a group.

<u>Spontaneous</u>

(a) The student(s) have just discovered something of value and need to share it with all.
(b) A group has finished an activity and needs to share preliminary results for others in the need to know.
(c) The teacher has just explained a strange observation/result and wants an individual or group to explain the new knowledge to others.

(d) A student learned/discovered something from recent work and wishes to share this with the teacher.
(e) Students have learned or discovered something of importance on TV, the Internet, or library. These are not expected to follow the format of planned presentations.

Planned by an individual
(a) The individual is presenting the group's data and/or results.
(b) The student was assigned a topic to report to the class.
(c) The individual has finished an individual part of an activity.
(d) The individual has discovered something that others in the class have missed, ignored, or did not comprehend the significance.
(e) A planned assignment is presented.

Planned by a group
This is a group presentation in which all members of the group present a specific part of an activity. Each student is responsible for a specific portion of a larger group summary of an activity. The format is simple and easy to follow by the class such as:
(a) A short *summary* of the presentation
(b) *Examples* of the equipment/materials used
(c) Use of a *journal*
(d) Drawings, charts and/or data tables as hard copy *handouts* or as a *slide* projected in class.
(e) *Question* and *discussion* period.

Certainly, there are other aspects of presentations, but these are suggested parts of the format that work well for middle school students. Rubrics should be provided to the student detailing what is expected and what parts of the presentations will earn points. Examples are provided at the end of the Introduction.

Standards

Each activity has a list of standards from the Pennsylvania Department of Education: Science and Technology (7th grade), Environment and Ecology (7th grade), and Math (8th grade). The complete standards are listed in the appendices for those not familiar with them. The activities have many more standards listed than are needed for most lesson plans. However, the instructor can choose which of the possible standards are best served for each specific activity. It is hoped that science and math instructors can interact and combine many activities to make these activities truly interdisciplinary.

Activities

For these activities to be successful, they need not all be completed or be completed in the order presented. However, for the best educational benefit to be achieved they must be used appropriately; that is to say, they are intended to be used as the foundation for an *inquiry* approach. They need to be researched by both the students and teacher and then discussed to achieve the most academic achievement. They are selected organized so that the knowledge, skills, and understanding of an ecological community will be enhanced.

Activities Habitat 1 and 2 are the foundation and are necessary for students to develop a sense of the total project. The statistics are very important for all middle school students, but it requires math discipline. However, they are not necessarily upper level math skills. Analysis of worm growth is the basis for most of the remaining activities. Counting and classifying worms is also needed to complete the majority of the remaining activities.

The next set of activities involves collecting data with sensors. These activities can be done without a data logger and sensors but the benefit of diurnal studies or week long studies will be lost – an important part of robust ecological studies. These activities can be used with the suggested Vernier sensors and Texas Instruments TI 83/84 calculator or with another set of sensors, data loggers, and graphing calculators. Certainly, traditional test kits and hardware can be used for many of these activities. However, for students to develop skills in scientific research, daily, 24-hour or weekly studies need to be completed. This requires data logging systems and modern sensor technology. To successfully meet some of the math standards the ability to use a graphing calculator is required. If microscopes are available to study the other inhabitants of the vermicompost, many more ecology standards can be met than suggested in these activities.

Worm behavior and response to light are classical studies and teach many important concepts that will be used in high school science classes. Prediction vs. actual value is one of the most important activities to be done after students have a grasp of the basic requirements for maintaining a successful habitat. The worms' reactions to non-optimal living conditions will provide the scaffolding for high school level ecology or AP Environmental Science classes. The growth of the worms as it relates to differing types of soils is fundamental to agriculture classes that are beginning to find a place in some schools again, as well as giving the students an opportunity to critique the enhanced growth of animals and plants on television. These activities, along with the Fast Plants® activities, can be the foundation for a rigorous science fair project. The expected results for these activities are known from the literature, except for the Mating Size activity. No solid and reliable results are known for this experiment. The results of exposure to NaCl is a classic example of university research that may provide benefit to those geographical regions that become exposed to heavy amounts of seawater or salt brine from hydrocarbon wells.

It is the hope of this author that exposure to these activities will provide both the "already interested" student with food for thought, as well as to motivate the bored or "turned off" potential science student.

Table of Contents

Resources........ ....Page xi – xii

Activity 1 ....Habitat 1 ....Page 1 – 4
Rationale: The data collected for the Habitat Activity will be used for other activities. This lesson also provides opportunities to study the physical characteristics of the Habitat over a continuous period of time.

Activity 2 ....Habitat 2 ....Page 5 – 7
Rationale: This activity looks at the data collected for the past six weeks. Careful analysis of the data will provide a foundation for most of the following activities.

Activity 3 ....Worm Growth...Page 8 – 11
Rationale: Much of the success of the Habitat will depend upon continued optimal environmental conditions for the worms. The most important measure would be the increase in worm mass. The change in mass of the worms can be used with other variables, such as a decrease in mass or volume of vermicompost.

Activity 4 ....Analysis of Worm Growth ....Page 12 – 14
Rationale: The data collected are important for the success of the Habitat. The analysis of these data will help determine how to modify the environmental conditions, if necessary.

Activity 5 ....Temperature of Vermiculture ....Page 15 – 17
Rationale: The temperature of the Habitat is crucial to its success. A data collection system needs to be used to collect data on a continuous basis. The easiest method is to use the system that interfaces with the Texas Instruments graphing calculator TI 83/84. The temperature and changes in temperature will affect the success of all of these activities. A constant (22 +/- 3^{o}C) temperature is optimum.

Activity 6 ....Smell of the Habitat..Page 18 – 19
Rationale: The odor or smell of the Habitat is an extremely good indicator of the heath of the vermiculture. This seemingly unimportant variable's measurement must be collected and recorded each day. Many times the change in odor will be the first signal that something is environmentally amiss.

Activity 7 ....Humidity of Habitat ....Page 20 – 22
Rationale: The wetness of the vermicompost is one of the variables that will have the most detrimental effect on the growth of the worms. One way to determine the wetness of the Habitat is to monitor the humidity of the air above the vermicompost. A too wet vermicompost will mask the correct earthy odor associated with a healthy Habitat.

Activity 8 ....Counting and Classifying Worms.......................Page 23 – 25

Rationale: The number of young worms in the vermiculture is a good indication of the health of the Habitat. The number of new hatchlings can be determined by sorting and counting. If the worms were sorted and counted carefully when they arrived or when a new Habitat was started, then the sizes and numbers at any time after that can be compared.

Activity 9 ....Carbon Dioxide..Page 26 – 28
Rationale: The amount of carbon dioxide is related directly to the metabolic activity. Thus these measurements are a very good indication of the rate of metabolism; that is, growth and reproduction. The amount of carbon dioxide above ambient values (ca. 400ppm) will be a quantitative measurement of the amount of activity by the worms.

Activity 10 ......Atmospheric O_2 of Vermicompost.....................Page 29 – 31
Rationale: The consumption of atmospheric O_2 is an indication of the health and rate of metabolism in the vermiculture. This is one more metabolic indicator of the overall efficiency of the Habitat.

Activity 11 ....Analysis of CO_2 Data..Page 32 – 33
Rationale: The amount of CO_2 produced by the worms can be measured directly and then related to other variables. To some extent non-worm decomposition of the garbage is also taking place and producing CO_2. In a later activity, students can pursue this corrective measure to the CO_2 collected during these simpler measurements.

Activity 12 ....The pH of the Habitat ....Page 34 – 36
Rationale: A healthy Habitat should have a pH that is slightly on the acid side. The optimum is pH of 6.5 +/- 0.2. However, it has been determined that *E. fetida* can tolerate a very wide range of pH conditions. Any rapid change towards acidic or alkaline conditions does need to be addressed immediately.

Activity 13 ....Worm Behavior...Page 37 – 38
Rationale: The usual species of worms used in vermiculture are considered to be phototropic, that is, they move towards light = positive (+) phototropism or move away from light = negative (-) phototropism. Vermiculture worms move away from BRIGHT light, but may be attracted to dim light. To what extent is the brightness related to the movement of the worms?

Activity 14 ....Degree of Avoidance to White Light...................Page 39 – 42
Rationale: It was determined that worms avoid bright white light in Activity 12. It is also important to know if the brightness has an effect on the worms. The students, with the aid of a light sensor, can determine if the worms react to differing intensities of light.

Activity 15 ....Worm Behavior with Light...................................Page 43 – 45
Rationale: White light will have a negative effect on worm behavior and it is possible that worms may not react to different colors of light. Counting and sorting worms can be frustrating and if the worms do not avoid one or more colors of light that result could be used to the students' advantages.

Activity 16 ....Response to Light by Age...................................Page 46 – 47
Rationale: From previous Activities 12, 13, and 14, the phototropic response to light was determined by intensity and by color. A question that remains: Does the response change with age of the worm? If the response is learned, then the older the worm is the quicker it will respond to bright light.

Activity 17 ....Mass of Input vs. Mass of Output........................Page 48 – 50
Rationale: The amount of foodstuffs added to the Habitat compared to the mass of runoff water and the increase in the mass of the worms should be related to the health of the Habitat. These data can be used to determine the efficiency of the system.

Activity 18 ....Analysis of Foodstuffs...Page 51 – 53
Rationale: The mass of foodstuff added and the chemical characteristics will help determine the effects of the foodstuffs on the Habitat.

Activity 19 ....Castings ....Page 54 – 56
Rationale: The amount of castings (excreta) is an important measure of the overall health of the Habitat. The mass of the castings is also related to the mass and age of the worms present.

Activity 20 ....Predictions vs. Actual..Page 57 – 58
Rationale: The counting/weighing to obtain the actual values for the worms, cocoons, and castings is a tedious and potentially harmful activity. To be able to take samples and accurately predict values is an important part of ecological research.

Activity 21 ....Determination of Food Choice by Age................Page 59 – 61
Rationale: The assumption could be made that all ages of worms prefer all types of food. This activity will take one feeding cycle and the worms need to be observed, sorted, and counted several times a day for the full feeding cycle.

Activity 22 ....Analysis of Run-off – Leachate or Tea................Page 62 – 64
Rationale: The run-off water at the bottom of the bin is an important aspect of the vermiculture. One of the scientific names best ascribed to this liquid is leachate. The traditional name is tea, because of its tea-like appearance.

Activity 23 ....Tolerance to Sodium Chloride by Weight...........Page 65 - 67
Rationale: Recently storms have caused fresh water soils to become contaminated with sea water. A recent study by M. Kerr and A.J Stewart in the *Journal of Undergraduate Research,* pp 21 -25*,* Volume III*,* 2003*,* completed a very straight forward study of salt water and *E. fetida*. The following activity is an adaptation of that study.

Activity 24 ....**Age Tolerance to Sodium Chloride ....Page 68 – 71**
Rationale: Recently storms have caused fresh water soils to become contaminated with sea water. A recent study by M. Kerr and A.J Stewart in the *Journal of*

Undergraduate Research, pp 21 -25, Volume III, 2003*,* completed a very straight forward study of salt water and *E. fetida*. The following activity is an adaptation of that study. The tolerance to salt by differing ages of worms is an important aspect of remediation of NaCl contaminated soils.

Activity 25 ....Tolerance of Cocoons and Hatchlings to NaCl ..Page 72 – 74
Rationale: Recently storms have caused fresh water soils to become contaminated with sea water. A recent study by M. Kerr and A.J Stewart in the *Journal of Undergraduate Research*, pp 21 -25, Volume III, 2003*,* completed a very straight forward study of salt water and *E. fetida*. The following activity is an adaptation of that study.

Activity 26 ....Tolerance to Overcrowding.................................Page 75 – 77
Rationale: At what point in time is the vermiculture too densely populated? Most critters have a tolerance for some overcrowding usually determined by the lack of food and/or abundance of waste.

Activity 27 ....Mating Size..Page 78 – 81
Rationale: Do worms select a particular size mate? This activity will attempt to determine the answer to this question. The activity is adapted from "Size-Assortive Mating in the Earthworm, *Eisenia fetida*"*,* Japan Ethnological Society*,* Springer Verlag, October 6th 2004, (on-line), Fernando Monroy, Manuel Aria, Alberto Veland, and Jorge Dominguez.

Activity 28 ....Growth with Egg Shells ....Page 82 – 86
Rationale: Many vermiculturists feel that egg shells or fine sand should be part of the diet. Vermiculture worms have a gizzard and small grains of sand or egg shells will remain in the gizzard to help scour/grind food stuffs for digestion. The egg shells (mostly $CaCO_3$) help to sweeten the vermicompost, as well.

Activity 29 ....Leaf Litter vs. Shredded Newsprint ....Page 87 – 90
Rationale: In nature leaf litter is a by-product of plant metabolism and can present disposal challenges. If leaves can be ground up into small bits can they be used in the Habitat instead of shredded newsprint? Additionally, will the leaves provide extra nutrients not available in newsprint alone?

Activity 30 ....Sterile Leaf Litter vs. Natural Leaf Litter ....Page 91 – 94
Rationale: To determine whether the microbial life attached to leaves is an important part of the digestive processes for the worms a study must be undertaken. The leaves must be free of microbial life (sterile) that may help in digestion and compared to leaves that are not sterile.

Activity 31 ....Fast Plants® and Castings..................................Page 95 – 98
Rationale: The castings and leachate may have some nutrient value for plants. The fast growing plants patented by the University of Wisconsin can be used to quickly determine if these vermiculture products have an effect on the growth of Fast Plants®.

Activity 32 ....Growth of Fast Plants® With Castings ....Page 99 – 105
Rationale: This Activity will be based on various masses of castings. The optimal mass can be determined by growing plants with differing masses of castings used as fertilizer.

Activity 33 ....Plant Growth with Leachate or Tea ....Page 106 – 112
Rationale: This Activity will be based on various masses of castings. The optimal mass can be determined by growing plants with different masses of castings used as fertilizer.

Activity 34 ....Plant Growth with Aqueous Castings ....Page 113 – 119
Rationale: This activity will be based on various masses of castings. The optimal mass can be determined by growing plants with differing masses of castings used as fertilizer.

Activity #35 ......Coir Vs Shredded Newsprint...............................Page 120 – 123
Rationale: In the food industry, coir (coconut husks) is a by-product of coconut farming and can present disposal challenges. If coconut husks can be ground up into small bits, can they be used instead of shredded newsprint? Additionally, will the coir provide extra nutrients not available in newsprint alone?

Appendix A ......PA Academic Standards for Science and Technology, Grade 7
....Page A1 – A7

Appendix B ......PA Academic Standards for Environment and Ecology, Grade 7
....Page B1 – B6

Appendix C ......PA Academic Standards for Math, Grade 8 ....Page C1 – C4

RESOURCES

BOOKS

Worms Eat My Garbage: How to Set Up & Maintain a Worm Composting System, Mary Appelhof , pp 162, Flower Press; Revised edition ISBN: 0942256107, (269) 327-0108, www.wormwoman.com.

Worms Eat Our Garbage: Classroom Activities for a Better Environment, Mary Appelhof, Mary Frances Fenton, Barbara Loss Harris, pp 214, Flower Press, ISBN: 0942256050

The Worm Cafe, Mid-Scale Vermicomposting of Lunchroom Wastes, Binet Payne, Paul E. Bourgeois, pp 200 , Flower Press, ISBN: 0942256115

Compost Critters, Bianca Lavies, pp 32, Dutton Books; 1st Ed., ISBN: 0525447636

The Rodale Book of Composting : Easy Methods for Every Gardener, Grace Gershuny (Editor), Deborah L. Martin Editor, pp 278, Rodale Books, ISBN: 0878579915

Recycle With Earthworms: The Red Wiggler Connection, Shelley C. Grossman, Toby Weitzel, Melissa Weitzel, Lucy Warren, Ed, pp 99 pages, Shields Publications, ISBN: 0914116320

The Soul of Soil: A Guide to Ecological Soil Management," 3rd Ed., Grace Gershuny and Joseph Smillie, pp 174, Ag Access Corporation; 3rd Ed., ISBN: 0932857167

The compost tea brewing manual, 4th Ed., Elaine R Ingham, pp 88 , Soil Foodweb, ASIN: B0006S6JVK

The Worm Book: The Complete Guide to Worms in Your Garden, Loren Nancarrow and Janet Hogan Taylor, pp 152, Ten Speed Press, ISBN: 0898159946

WEBSITES

http://www.wormwoman.com

http://www.vermiculture.com

http://www.cityfarmer.org/wormcomp61.html

http://www.yelmworms.com/vermiculture

http://whatcom.wsu.edu/ag/compost/mrcworms.htm

VIDEOS

Wormania! Flowerfield Enterprises, VHS, 26 min, with 48p teaching guide ISBN: 0-942256-09-3

Worm Bin Creatures Alive Through a Microscope, Warren Hatch, distributed by Flowerfield Enterprises Specs: VHS, 31 min ISBN: 0-884195-35-0

REFERENCES

Avoidance Test with Eisenia fetida as Indicator for the Habitat Function of Soils: Results of a Laboratory Comparison Test, Hund-Rinke, Kerstin, Journal of Soils and Sediments, 1: 7-12,2003

Cocoon Production, Morphology, Hatching Patterns, and Fecundity in 7 Tropical Species of Earthworms, G Bhattacharjee and P.S Chaudhuri, Journal Bioscience, V 27, 3, June, 283 – 294, 2002

Comparative studies on biomass production, life cycles and composting efficiency of E. fetida and L.Mauritii, Tripathi G, Bhardwaj P. Department of Zoology, JNV University, D-41, Saraswati Nagar, New Pali Road, Jodhpur 342-001, India

Effect of UV radiation on Eisenia fetida populations Hamman A, et. al. Pedobiologia, 47: 5-6, January 2004, pp. 842-845

Size-assortative mating in the earthworm, E. fedita, Journal of Ethnology, Japan, Fernando Monroy, et. al.,26:69-70, 2005

Tolerance Test for E. Fetida, with Sodium Chloride, M. Kerr and A.J. Stewart, U.S Department of Energy, Journal of undergraduate Research, pp 21 -26, 2004

Activity 1

Habitat

Rationale: The data collected for the Habitat Activity will be used for other activities. This lesson also provides opportunities to study the physical characteristics of the Habitat over a continuous period of time.

Objectives

One or more websites, videos, texts, etc should be explored, studied, discussed by the students before this vermiculture activity is started. The students need to have several completed lessons on vermiculture before beginning these activities. The inquiry approach for these activities is best accomplished when the students are already familiar with the task at hand. A successful worm bin should be on hand as an example.

1) Measure, record, and analyze the physical constants of the Habitat.
2) Collect data on selected variables of the Habitat.
3) Record the data in a journal and Data Table 1.
4) Record and analyze the data collected over a period of time (Activity 2).
    a. Rate of change in the mass of vermicompost
    b. Rate of change in the volume of vermicompost
5) Analyze, discuss, and predict future effects on the Habitat.
6) Recommend any changes deemed necessary.

PDE Standards

<u>Science and Technology</u>
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
<u>Environment and Ecology</u>
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
<u>Math</u>
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.10.8. A,B
2.11.8. A,B

Materials

Worm bin
Scales (bathroom)
Rulers
Flexible tape measure
Graphing calculator (optional)
Graphical Analysis (software)
Breeder worms

Introduction

The physical characteristics of the Habitat are very important. The students will collect and record the following data in Data Table 1: the amount of space occupied by the bedding, the volume of air above the bedding, the mass of the bedding, and the volume of the bedding. The students, with guidance/coaching, will decide how to collect the data and how often to collect the data.

The change in volume and mass of the bedding will give students an indication of the environmental quality of the Habitat. As these data are collected and analyzed, the students will begin to develop a quantitative record of the health of the Habitat.

Strategies

This activity is best done with minimal guidance if you want students to develop a sense of inquiry. Have each group “brain storm” the possible constants and variables needed. Have each group report to the whole class, providing a short period of time for questions, answers, and advice. Each group should then discuss the information and advice received from their classmates. They should revise and turn in the data table. The data table will then be evaluated and returned to the student/group for revising or to be used by that group. An acceptable data table format must be completed by each group before the next activity period.

Procedure

This will vary from class to class as the groups develop their personal plans for the collection, recording, and analysis of data. A typical procedure is outlined below.

1) Record the mass of the empty clean bin (do not forget the lid).
2) Record the volume of the bin.
    a. This will require the use of some geometry and some estimation (corners).
    b. A height scale in centimeters should be developed and placed on two sides of the bin. This will allow students to quickly determine the height of the bedding (vermicompost).
    c. The ***average area*** (sum of bottom and top area divided by 2) will need to be calculated each time if a commercial bin is used.
    d. If commercial bins are not used and a rectangular bin has been constructed, the area will remain the same.
3) Record the mass of added bedding in the journal and Data Table 1.
4) Record the mass of added water in the journal and Data Table 1.

Expectations

The students should be able to:

1) set up the Habitat and understand what constants and variables are needed for this project.

2) determine reasonable time periods for the collection of the data that need to be selected. However, as part of a true inquiry approach, student groups need to be given a chance to make less than perfect decisions. (These decisions should be correctable.)
3) make arrangements for removing the liquid that will collect at the bottom of the bin. The mass of this liquid must be recorded.

Data Table 1 *(Typical Table)*

Date	Mass of vermicompost (kg)	Mass of worms (g)	Volume of vermicompost (cm^3, dm^3 or L)	Mass of liquid removed (cm^3 or mL)*	Mass of food added (kg)

*** 1 cm^3 or mL = 1 gram**

Data Table 1a *Typical work table*

Mass of bin/ vermicompost (g)	Mass of bin (g)	Mass of vermicompost (g)	Height (cm)	Width (cm)*	Length (cm)*	Volume of vermicompost (cm^3)

* If a commercial bin is used, the average of the area of the top and bottom is needed to get an average area; then multiply by height for volume.

Activity 2

Habitat 2

Rationale: This activity looks at the data collected for the past six weeks. Careful analysis of the data will provide a foundation for most of the following activities.

Objectives

1) Design an experiment to determine the rate of decomposition.
2) Design an experiment to determine the rate of growth of the worms.

PDE Standards

Science and Technology
3.1.7 A,B,C
3.2.7 A,B,C,D,E,F
3.5.7. D
3.6.7. A,B
3.7.7. A,B,C,D
Environment and Ecology
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
Math
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.10.8. A,B
2.11.8. A,B

Materials

Bin
Scale (Bin)
Balance (worms)
25-mL graduated cylinders

Introduction

The Habitat will be a contained space of many metabolic activities. The worms' food "garbage" will begin to decay microbially and the worms will also break down the food by carrying on normal metabolic activities. These metabolic activities are easy to measure and analyze. In regards to burying the food many vermiculture experts suggest that a feeding grid should be established and strictly adhered to; others suggest the food should be mixed thoroughly in the entire top layer (2 to 3 cm thick). One method should be selected and continued for the course of the experiment. This Activity needs to be started with breeder worms, not bedding worms.

Strategies

Before this activity is started have students determine what variables would be best suited to determine the quality of the Habitat. Discuss the activities the worms carry on each day and how best to measure these variables. As stated before, these activities are intended to be used with the inquiry approach to learning science. Students should discuss the biological and chemical activities taking place in the bin. Some teachers have a bin filled with bedding and make it into a hot-compost heap to compare with data collected from the worm bin. For the following experiments, the data collected will act as a "control," comparing the new data to the average of the previous data or the recorded trends. Many real science experiments do not have controls.

Procedure

The procedures will vary from class to class, but basically the students need to select a specified number of variables to study and decide how to best collect the data. If only one large worm bin is available, each group should pick/designate a different set of variables. The best method is to have a small bin for each group and each group will have one or more variables common to all groups and a few specific variables. The following are a list of possible variables that can be studied. This list is by no means complete.

1) Mass of food added
2) Mass of run off water
3) Mass of vermicompost
4) Mass of worms
5) Number of worms
6) Average mass of the worms
7) Temperature
8) Relative humidity
9) pH of vermicompost
10) pH of run-off water
11) Amount of $CO_2(g)$ above the vermicompost
12) Amount of $O_2(g)$ above the vermicompost
13) Length of individual worms
14) Density of the compost
15) Aversion to light

Actual lesson plans for most of the above will follow, as well as additional activities. It is imperative that students design as much of the experiment as possible, with guidance.

Typical students' ideas

1) Sort, weigh, and count the worms every week and chart their growth.
2) Weigh the vermicompost and determine the rate of decay.
3) Count the number of worms and chart the increase in the population.

4) Compare the mass of the food added to the change in mass of the worms and vermicompost.
5) Determine the amount of heat produced by the vermicompost and lost to the environment (a possible project though too complicated for MS).

Expectations

The students will be able to develop:

1) a sense of how real scientific experimentation occurs.
2) a sense of what are variables and constants.
3) a workable method for collecting data on selected variables.
4) several drafts of the experimental procedures.
5) several tables for recording data.
6) an understanding of dependent and independent variables.

Activity 3

Worm Growth

Rationale: Much of the success of the Habitat will depend upon continued optimal environmental conditions for the worms. The most important measure would be the increase in worm mass. The change in mass of the worms can be used with other variables, such as a decrease in mass or volume of vermicompost.

Objectives

1) Design a method for collecting all of the worms.
2) Develop an understanding about the connection between environmental variables and change in the mass of worms.
3) Develop an understanding about which environmental variables may be causing changes in worm mass.
4) Develop a sense of how to determine which variable(s) is causing the change in mass.
5) Develop an understanding of the accuracy and precision needed for the correct measurement of the variables.

PDE Standards

<u>Science and Technology</u>
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
<u>Environment and Ecology</u>
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
<u>Math</u>
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

Bin
Balance (centigram)
Light source
Protective gloves
1-L plastic food container
White poster board, nonabsorbent

Introduction

The best way to determine the health of the Habitat is to analyze the growth data. One of the best procedures is to measure the total mass of the worms at selected intervals. This requires a careful removal of the worms from the vermicompost. The worms should be decomposing the garbage/food, metabolizing the food as stored energy, and converting it to body mass, eggs, and new worms. However, if environmental conditions in the Habitat are not ideal or only near ideal, a slight increase in mass may occur, but new worms will be in very short supply.

Strategies

The standard deviation and variance can be omitted. However, the calculator can calculate both and students can experience using the results without a complete understanding of the mathematics involved. One of the overarching concepts of this and future activities is to determine the environmental conditions that influence the growth of worms. The easiest procedure is to weigh the worms every week -- after the Habitat is well established. Under certain conditions the worms will grow well and their numbers as well as their total mass will increase. These changes in mass can be compared to the recorded conditions in the Habitat. Of course, if the class has more than one habitat each Habitat can be used for selected variables. Use one or more Table 1s to record the mass and the environmental variable(s) conditions for each Habitat. Try not to crush or destroy any of the small 3 – 4 mm cocoons. Each cocoon contains 1 – 3 small eggs that can hatch into small worms.

Procedure

1) Remove about ½ of a liter of vermicompost and place it in a pile on a white poster board. Repeat this with the remaining vermicompost.
2) Shine a 200 watt light bulb on the piles. Gently remove the outer layers of each pile and place any worms caught into the weighing box. Most of the worms will go the bottom center and you will eventually have them all corralled.
3) Tare the weighing box before adding any worms or record the mass of the box in the journal and in Table 1.
4) Record the mass of the clean worms in the journal and in Table 1.

Expectations

The students should be able to:

1) notice a change in the mass of the worms and the number of new worms (small).
2) note the conditions of the vermicompost: dampness, smell, and temperature.
3) determine the rate of growth in grams/week and % change/week.
4) determine the rate of change by entering the data (mass in List 2 and the time interval in List 1) into the graphing calculator and perform a linear regression on List 1 versus List 2.

Data Table 1 *(Typical Table)*

Time (weeks)	Mass of box (g)	Mass of worms and box (g)	Mass of worms (g)	Mass of worms in previous week (g)	Change in Mass (Δg)
				XXXXXX	

Data Table 2 *(Typical Table)*

Date	Mass of worms	Temp	Humidity	Smell

Data Table 1 for Activity 17 (needs to be started immediately)

Data Table 1 *(Typical Table)* **Mass of Foodstuffs Added**

Date	Fruits	Gr. Leafy Vegetables	Solid vegetables	Cereals	Legumes	Tubers

Activity 4

Analysis of Worm Growth

Rationale: The data collected are important for the success of the Habitat. The analysis of these data will help determine how to modify the environmental conditions, if necessary.

Objectives

1) Analyze the worm growth data by hand.
2) Perform a one-variable statistic on the data.
3) Compare the hand derived values to the calculated values.
4) Determine the mean (average), maximum, minimum, range, variance, and standard deviation.
5) Determine which of the above analyses are best for determining the optimum Habitat conditions.

PDE Standards

Environment and Ecology

4.1.7. A,B,C
4.2.7. A,C
4.3.7. B
4.6.7. A,B,C

Math

2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

Graphing calculator
Computer
Graphical Analysis (software)
Data from Worm Growth Activity

Introduction

This activity will familiarize the students with the statistics applications on the graphing calculator as well as the meaning and use of several common statistical analyses. The mean or average is the sum of the data collected divided by the number of data points. The range is the difference between the maximum value and the minimum value. The variance is the average of the differences between the measurement and the mean squared.

$$\text{variance} = \frac{\text{sum of the (measurement – average*)}^2}{\text{number of measurements}}$$

The standard deviation is the square root of the variance, $\sqrt[2]{\text{variance}}$.
* This is the average of each group's values.

Strategies

Ideally the students should play a large role in determining the analysis of the data. However, they will need to begin at a fundamental level. The average of the measurements will help them become familiar with analysis of data and the power of a graphing calculator. Have the students calculate the average by hand on the calculator by averaging the mass measurements from Data Table 1 of Worm Growth Activity. These data can be then entered into the appropriate calculator list. Students should complete Data Table 1 for this activity. One variable statistics (1-Var Stats) will give them the calculated mean or average. The students should complete the calculation for the variance and standard deviation. Then they should compare the range to the variance and standard deviation. Have students describe what they observed by writing a short essay. If time permits have them explain and or present their findings.

Procedure

1) Enter the change in mass measurements into the calculator and find the average. Record the data in Table 1.
2) Enter the same data into List 1. Select STAT, EDIT, "1-var Stats," and then press ENTER. The value after $\bar{x}$ is the average. Compare the average to the measured mass. If different by more than a tenth, consult the teacher.
3) Complete the columns in Data Table 1 for variance.
4) Take the square root of the variance, $\sqrt{\text{variance}}$.
5) Compare to the standard deviation, Sx (found in 1-var Stats).

Expectations

The student should be able to**:**

1) determine the average, range, max and min by hand and compare to the STAT values.
2) determine the differences between average measurements, square the values, and find the average - variance.
3) take the $\sqrt[2]{\ }$ variance - square root of the variance.
4) complete Data Table 1 and determine the standard deviation.
5) develop an understanding of how the change in mass is a result of the conditions of the Habitat.

Data Table 1

Mass	Ave	Mass – Ave	(Mass – Ave)^2
		XXXXXX	XXXXX

<u>Show all work (in journal)</u>

1) Average of changes in mass __________
2) Maximum__________, Minimum __________, Range ___________
3) Sum of the [differences squared] ___________
4) Number of measurements _____________
5) Variance __________, Range _____________, Difference ____________
6) Standard deviation __________, Range _________,Difference _________

Extensions

1) What observations were made?
2) What explanations support the observations?

Activity 5

Temperature of Vermiculture

Rationale: The temperature of the Habitat is crucial to its success. A data collection system needs to be used to collect data on a continuous basis. The easiest method is to use the system that interfaces with the Texas Instruments graphing calculator TI 83/84. The temperature and changes in temperature will affect the success of all of these activities. A constant (22 +/- 3^{o}C) temperature is optimum.

Objectives

1) Set up a system for collected temperature data.
2) Determine the optimum intervals.
3) Compare the temperature of the Habitat with the ambient temperature.
4) Determine if any insulation is necessary to maintain a constant temperature.
5) Learn how to use the DataMate application.

PDE Standards

Science and Technology

3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D

Environment and Ecology

4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C

Math

2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

Class Habitat
Temperature sensor
Graphing calculator
Computer
Graphical Analysis

Introduction

The rate of metabolism is controlled by the temperature of the worms. To some extent this metabolic process produces excess heat energy as well as the composting/decomposition reactions that are also taking place in the Habitat. The ambient temperature of the room affects the rate at which the Habitat loses or gains heat. Too low of a temperature -- the metabolic reactions proceed too slowly; too high of a temperature - - the reactions proceed very fast. To an extent, large variations in temperature may cause the worms to not metabolize correctly, breed and not reproduce, or die. Most worms used for vermiculture metabolize best between 15°C and 25 °C. Most do best at 22°C +/- 3 °C. The Habitat should not sit on a table that gets direct sunlight or in the stream of cool air from an AC vent.

Strategies

Help the students decide on the number of temperature readings to record each day and the interval between the readings. With the CBL2 system, TI 83/84, and temperature sensor, readings can be taken every few minutes for a week at a time. However, the temperature readings will probably only change significantly when the lid is open, worms are counted, at night when the school temperature is lower, the AC turns off and on, and over weekends. To have these readings and to be able to compare them to the changes in worm mass will help determine the optimum temperature. If the optimum temperature cannot be maintained, the Habitat can be put inside a larger box or a larger bin with shredded paper between all sides, bottom, and the top of the worm bin. Too much humidity and/or too much moisture in the vermicompost will also cause large fluctuations in temperature.

Procedure

1) Set up the DataMate application to collect data with the appropriate temperature sensors.
2) Students should decide on the number of data points (temperature readings) collected per 24 hours, diurnal. 24 or 48 are good starting values. Every ½ hour or every hour for 7 days will be a total of 168 and 336, respectively.
3) Set up the CBL2 with three appropriate temperature sensors. One sensor is on the outside of the Habitat and the other two should be placed in the vermicompost at places decided upon by the students.
4) Collect the data for a week. Download the data to a computer via Graphical Analysis. Complete a 1-Var Stat on the data for the week.
5) Separate out the data by days and complete a 1-Var Stat analysis for each day.
6) Using the statistic button to calculate 1-Var Stat on each day and compare to the values for the 1-Var Stat for the week.
7) Were any diurnal means (averages) farther from the weekly mean than others? What days were they? What can be done to correct these temperature fluctuations?
8) What were the diurnal standard deviations? Compare them to the weekly standard deviations.
9) Place the weekly standard deviation in the last cell in the last column.
10) Attach a print out of the weekly temperature readings from Graphical Analysis.

Expectations

The students should be able to:

1) use the DataMate application and set up more than one sensor.
2) make good decisions about the time interval between readings.
3) make better decisions about the location of the Habitat and the sensors in or around the Habitat.
4) recall how to do a 1-Var Stat and recall the meaning of mean/average, range, and standard deviation.

Data Table 1

Day	Average temp	Range of temp Max	Min	Standard deviation
1				
2				
3				
4				
5				
6				
7				
Average of following values				

Activity 6

Smell of the Habitat

Rationale: The odor or smell of the Habitat is an extremely good indicator of the heath of the vermiculture. This seemingly unimportant variable's measurement must be collected and recorded each day. Many times the change in odor will be the first signal that something is environmentally amiss.

Objectives

1) Determine an adequate odor scale for each Habitat.
2) Discuss and agree upon a set of four to six odor descriptors.
3) Realize that it is difficult to easily graph temperature or humidity vs. descriptors.
4) Derive a sequential number value for each descriptor.
5) Present/explain a system to peers.

PDE Standards

Science and Technology
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
Environment and Ecology
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C

Materials

Habitat

Introduction

The odor of the vermicompost is an excellent qualitative measure of Habitat health. The odor associated with garbage may be present for a short time after adding it to the vermicompost and should not be confused with the presence of rotting garbage. If the Habitat is not healthy, the worms will not decompose the garbage in a normal time frame. Also, if the worms are healthy and too much worm food has been added, a garbage odor will be present for a longer period of time than normal. Therefore, the worms cannot keep up with the excess food. This will also occur sometimes after harvesting worms since the same amount of food will be added and there are too few worms to decompose that amount of food.

Strategies

The ideal situation will be to have students with a refined sense of smell volunteer to be in the odor sensor group. It may be difficult for students to not gag at an unhealthy habitat. Some encouragement may be necessary from the teacher. Students with a too refined sense of smell will get carried away with the number of descriptors. Students without a refined sense of smell will not be discerning enough. Have students design a descriptor system that resembles a box of crayons with ONLY 8 colors, not the 48 or 96 color pack. The students will need to have access to 5 or 6 stages of decomposition for this to work really well. This activity is best with a Habitat set up by the teacher.

Procedure

1) Students should decide who will be the group of odor sensors.
2) Odor sensors should design a set of odor descriptors.
3) Odor sensors should assign a sequential set of number values to the descriptors.
4) The odor sensors should present the odor scale to the class and describe the rationale for the system.

Expectations

The students should to be able to:

1) develop a reasonable odor scale.
2) develop the ability to compromise.
3) record observations and effects in the journal.

Data Table 1 ***(Typical Table at this point in time)*** Optional Optional Optional

Date	Smell (scale)	Δ Mass*	Temp	Humidity (%)	pH	CO_2 (ppm)	O_2 (%)

* = **Δ Mass (g) = change in mass**

Activity 7

Humidity of Habitat

Rationale: The wetness of the vermicompost is one of the variables that will have the most detrimental effect on the growth of the worms. One way to determine the wetness of the Habitat is to monitor the humidity of the air above the vermicompost. A too wet vermicompost will mask the correct earthy odor associated with a healthy Habitat.

Objectives

1) Determine the humidity of the air above the vermicompost.
2) Use the humidity value area measure of the wetness of the vermicompost.
3) Compare the humidity of the air with the actual water content of the vermicompost.
4) Compare the relationship between the humidity, water content, and growth of the worms.
5) Compare and correlate the smell value associated with Activity 3 with the humidity of the air above the Habitat.

PDE Standards

<u>Science and Technology</u>
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.5.7. D
3.6.7. A,B
3.7.7. A,B,C,D
<u>Environment and Ecology</u>
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
<u>Math</u>
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

CBL2
Humidity sensor
TI 83/84
Computer
Graphical Analysis
Duct tape

Introduction

The water content of the vermicompost should not exceed 2 to 3 times the mass of the original mass of the shredded paper, 60 – 70% moisture. This may be very difficult to maintain, especially after adding fresh food. When the vermicompost is maintained correctly, the water content of a healthy Habitat will not exceed 60 – 70% of the mass of the worms, castings, and partially decomposed food. If excessive water appears in the bottom of the worm bin the total water content will be too high. To help maintain a healthy vermicompost, monitoring the humidity will prove to be well correlated with the water content of the vermicompost.

Strategies

Have students discuss within their groups how to best monitor the water content of the vermicompost. One of the easiest methods is to physically weigh the vermicompost and monitor any changes. However, whenever samples are collected for weighing, the vermiculture is shocked, which will lead to a day or more of re-habitation. Also the water content will be much higher near the bottom of the vermicompost than at the top. Once the students decide to also use a humidity sensor, the same thought processes that went into establishing a data collection schedule for the temperature measurements should ensue. However, a correlation must be established and weighing samples of vermicompost and comparing those masses to the humidity must be established. Once the relationship has been established very few, if any weighings of vermicompost will need to be done for only water content. However, the lack of an earthy smell to the vermicompost will occur within a few days of excessive humidity readings.

Procedure

1) Press the APPS button and select DataMate.
2) Set up the CBL2/TI 83/84 to record humidity values.
3) Place the humidity sensor near one of the “exiting” air holes in the Habitat.
4) Use duct tape to hold the sensor in place.
5) Remove all worms, castings, cocoons from several samples, dry under a heat lamp, and weigh the dry compost.
6) Determine the average water content of each sample of the vermicompost. Record the mass of the samples in Data Table 1.
7) Download the humidity measurements to the computer using Graphical Analysis.
8) Fill in Data Table 1 for this activity.
9) Determine what sets of humidity measurements should be entered into Data Table 1.
10) Determine what humidity values in percent relative humidity correlate to water content.

Data Table 1

Date (time)	Sample 1 Mass	Sample 2 Mass	Sample 3 Mass	Average Mass	Relative Humidity	Odor Scale

Expectations
The students should be able to:
1) work together and determine the most appropriate time schedule for collecting humidity measurements.
2) suggest that only two temperature sensors are needed. The same CBL2 can be used to collect humidity measurements, as well.
3) decide what relative humidity data values relate to a too-high water content and what relative humidity values relate to lower or optimal water content values.
4) decide/compromise on a set of five or six smell descriptors.

The following is a common set of odor descriptors with +/ – number values or all + number values.

Typical odor/smell descriptors and number values scales

Odor Descriptor	Putrid	Rotting	Marshy	Garbage	Non – descript	Earthy
# Value	1	2	3	4	5	6
# value	-2	-1	0	1	2	3

Activity 8

Counting and Classifying Worms

Rationale: The number of young worms in the vermiculture is a good indication of the health of the Habitat. The number of new hatchlings can be determined by sorting and counting. If the worms were sorted and counted carefully when they arrived or when a new Habitat was started, then the sizes and numbers at any time after that can be compared.

Objectives

1) Learn how to sort and size worms.
2) Determine how size relates to maturity or age of the worms.
3) Sort, count, and record measurements accurately.
4) Display the measurements in graphical form.
5) Analyze the measurements and use this analysis in later activities.

PDE Standards

Science and Technology

3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D

Math

2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

Habitat worms
Rulers
Balance, centigram
Plastic weighing pans
Spatulas

Introduction

The newly hatched, healthy worm is between 2 – 3.5 cm long and at reproductive maturity averages about 6 – 10 cm, with a maximum of 13 – 14 cm. Under optimum conditions the worms can double in mass every three months. The average incubation period for the worms is between 32 and 73 days, depending on the Habitat's conditions. Healthy, sexually mature worms (*E. fetida* or *E. andrei*) will produce about four cocoons/week. The hatching rate can be anywhere between 70% and 90% with optimum conditions. About 3 – 4 hatchlings/cocoons will survive in a cocoon. This will yield between 10 to 15 young per week per adult. The average time for *E. fetida* cocoons to hatch is between 1 – 2 ½ months. After hatching it will take 2 - 2 ½ months to reach reproductive maturity; a band or clitellum will appear. Between 3 and 5 months the amount can increase by nearly an order of magnitude. However, the Habitat will have a maximum carrying capacity; this means the mass of the worms can maximally double every 3 – 4 months. If a small amount of worms was started with – 100 grams – the spectacular population explosion is more likely to occur during the first one or two cycles.

Strategies

This activity can be completed earlier if the class habitat was stocked with bed-worms instead of breeder-worms. Students should read articles or find websites devoted to vermiculture to become well versed in the anatomy, physiology, reproduction, and optimum environmental conditions. Then they should decide on a system of classifying the worms. The students should also find pictures of *E. fetida*, *E. andrei*, or the worms used in the Habitat. Pictures showing how to collect, wash, count, weigh, sort , etc. the worms should be readily available to all students. The best classification system is the one the students devise, but usually the teacher must intervene. Data Table 1 is a typical classification system. Of course, this is the activity that is the most invasive and potentially dangerous to the vermiculture. It is imperative the students be very careful and not injure any worms. If any worms are injured they must be separated from the culture; injured/dying/dead worms can potentially have serious effects on the Habitat unless they are replaced.

Procedure

CAREFULLY CAREFULLY!!!!

1) Collect all of the worms in a dimly lit place.
2) Wash (water temperature the same as the Habitat's) the detritus off of them.
3) Place them on paper towels and blot fairly dry just for weighing.
4) Weigh the total amount.
5) Sort into the devised classes (be sure to keep them moist).
6) Record pertinent data in the journal and Data Table 1.

.

Expectations

The students should be able to:

1) make decisions about a classification system.
2) develop good methods for handling worms quickly and carefully.
3) sort carefully and accurately.

<u>Typical Classification system</u>

Hatchling: 1 – 3 cm
Juvenile: >than 3 cm, but no band (clitellum)
Mature: has band (clitellum)

Data Table 1 (*Typical table)*

Date	Ave Mass Worm	Hatchlings totals		Ave Mass Worm	Juveniles totals		Ave Mass worm	Mature totals		Total # of Worms
		#	Mass		#	Mass		#	Mass	

Activity 9

Carbon Dioxide

Rationale: The amount of carbon dioxide is related directly to the metabolic activity. Thus these measurements are a very good indication of the rate of metabolism; that is, growth and reproduction. The amount of carbon dioxide above ambient values (ca. 400ppm) will be a quantitative measurement of the amount of activity by the worms.

Objectives

1) Determine the amount of carbon dioxide produced by the worms.
2) Determine if the amount of carbon dioxide produced is related to any of the other measurements.

PDE Standards

Science and Technology
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
Environment and Ecology
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
Math
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

Carbon dioxide sensor
CBL2
TI 83/84
Computer
Graphical Analysis
Duct tape

Introduction

The amount of CO_2 produced diurnally will be a valuable indicator of worm growth. The worms carry on cellular respiration 24 hours a day. The nearer the physical conditions in the vermicompost are to the optimum, the greater the amount of cellular respiration. The amount of CO_2 produced above the ambient value under optimum conditions will be related to the mass of the worms. The CO_2 will be produced by the worms in the vermicompost and it will diffuse rather rapidly to the surface and into the air space above.

Strategies

It would be ideal if the students could be guided into discovering/recalling the above information before this activity is designed. The carbon dioxide sensor uses a laser to excite a photo receptor (detector) – the frequency of the laser light is absorbed by carbon dioxide. Thus the more carbon dioxide in the air, the more the laser light is absorbed; the lower the amount of reference laser light reaching the detector, the greater the amount of CO_2. Once again, the students should determine the time schedule for the data collection.

Procedure

1) Press the APPS button and select DataMate.
2) Set up the CBL/TI 83/84 for the CO_2 sensor.
3) Duct tape the sensor to the bottom of the lid.
4) Start the data collection.
5) At the end of the collection period, download the data using Graphical Analysis.
6) Attach a copy of the data to this activity.
7) Enter the CO_2 data into List 1 and add other data sets that will help determine if the amount of CO_2 is related to worm growth.
8) Perform several linear regressions with CO_2 measurements and other variable measurements.

Expectations

The students should be able to:

1) determine a meaningful time schedule for data collection.
2) program the Datamate program with coaching.
3) decide how to compare CO_2 measurements to other variables.
4) design the Data Table(s), methods, and present/explain the ideas to the class. (Groups)

Data Table 1 ***(Typical Table at this point in time)***

Date	CO_2	Δ Mass*	Temp	Humidity	pH	Smell (scale)	O_2 (%)

* = **Δ Mass (g) = change in mass**

1) Discuss the relationship(s) between the ppm of CO_2 above 400 ppm and the variable(s) that were compared.
2) Discuss why some variables are not related to the ppm of CO_2.

Activity 10

Atmospheric O_2 Content of Vermicompost

Rationale: The consumption of atmospheric O_2 is an indication of the health and rate of metabolism in the vermiculture. This is one more metabolic indicator of the overall efficiency of the Habitat.

Objectives

1) Determine the rate of O_2.
2) Compare the O_2 rate to other metabolic indicators.
3) Determine the agreement of the relationship with the actual data points.

PDE Standards

Science and Technology
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
Environment and Ecology
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
Math
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

CBL2
TI 83/84
Computer
Oxygen sensor
Graphical Analysis (software)

Introduction

The worms consume O_2 24 hours a day and produce CO_2 24 hours a day. The consumption of CO_2 has already been documented in Activity 8 and now the relationship between CO_2 production and O_2 consumption will be documented. The O_2 sensor measures the amount of O_2 in the sample compared to the normal amount of O_2 present in the atmosphere, that is, the sensor will reproduce the normal amount of O_2 as about 19% in the classroom and in an active vermicompost, a reading below the room reading.

Strategies

The students will need very little coaching for this experiment if most of the other inquiry activities have been completed. Students should read about the O_2 sensor and discuss, in groups, how to best design the experiment. A review of metabolism and the composition of the atmosphere may be necessary. The students should be able to determine what other variables, from previous experiments, can be studied to observe any relationships.

Procedure

1) Press the APPS button and select DataMate.
2) Set up the O_2 sensor for the appropriate sampling length and interval.
3) Carefully excavate an indentation in the vermicompost around a 250-mL beaker.
4) Mount the O_2 sensor under the bib lid so the detector end of the sensor is in the indentation, BUT not touching any vermicompost. (This is best accomplished with a wire frame resting on the vermicompost.)
5) Download the data to the computer and attach a set of the data to this activity.

Optional

6) Press the 2^{nd} function key and then the “0” key (catalog).
7) Press the ‘x^{-1}’ key (letter D).
8) Scroll down to DiagnosticOn and press enter.
9) Perform a linear regression on the two variables in question.
10) When the slope is displayed, numerical values for “r” and “r^2” will be, also.
11) The “r” value will be a number between 0 and 1. The closer the value is to 1, the closer the data points (coordinate pairs) are to the best fit line.
12) Draw conclusions from the results.

Expectations

The students should be able to:

1) design the experiment.
2) design a Data Table.
3) set up the experiment.
4) program the DataMate application.
5) collect the data and analyze the data.
6) determine if other variables have a relationship.
7) draw conclusions from the results obtained.

Data Table 1 *(Typical student data table)*

Date	O_2	CO_2	?	?	?	?

Data Table 2 *(optional)*

Variable 1	Variable 2	Slope	r
O_2	CO_2		
O_2	?		
O_2	?		
O_2	?		
O_2	?		

Activity 11

Analysis of CO_2 Data

Rationale: The amount of CO_2 produced by the worms can be measured directly and then related to other variables. To some extent non-worm decomposition of the garbage is also taking place and producing CO_2. In a later activity, students can pursue this corrective measure to the CO_2 collected during these simpler measurements.

Objectives

1) Make decisions about what variables may have a relationship.
2) Enter data into a graphing calculator.
3) Select the proper regression.

PDE Standards

<u>Science and Technology</u>
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
<u>Environment and Ecology</u>
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
<u>Math</u>
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

TI 83/84
Graphical Analysis (software)
Computer

Introduction

Cellular respiration is carried on by all living members of the animal Kingdom. *E. fetida* or *E. andrei*, the red worms used in the vermiculture are typical annelids. The worms carry on cellular respiration by absorbing oxygen through the skin and releasing CO_2 by the same process. The previous activities have taken advantage of these traits and the CO_2 measurements will aid in the study of growth and reproduction (fecundity).

The amount of CO_2 released, compared to the increase in worm mass, should show a direct relationship.

Strategies

Students will need to review the concept of cellular respiration in animals. The release of CO_2 gas as a by-product of cellular respiration is important for an understanding of how the amount of CO_2 *released* can be related to growth and maintenance. Show the students that a direct relationship exists between the amount of O_2 absorbed through the moist skin of the worms and the amount of CO_2 released.

Procedure

1) Use the data from Data Table 1 in Activity 8 for this Activity.
2) Enter the selected data into the proper lists.
3) Find the range, max, min, and standard deviation for each list.
4) Perform a linear regression on selected lists to determine if there is a relationship.
5) Record the values in Data Table 1.

Expectations

The students should be able to:

1) observe and realize that trends near or on a specific date are important.
2) perform a 1-Var Stat on selected data.
3) select the variables that have relationships.
4) perform a linear regression on selected Lists (variables).

Data Table 1 *(Typical Table)*

Variable	Maximum	Minimum	Range	Standard Deviation	Slope (+/-)

Activity 12

The pH of the Habitat

Rationale: A healthy Habitat should have a pH that is slightly on the acid side. The optimum is pH of 6.5 +/- 0.2. However, it has been determined that *E. fetida* can tolerate a very wide range of pH conditions. Any rapid change towards acidic or alkaline conditions does need to be addressed immediately.

Objectives

1) Learn the basics of acids and bases as they relate to vermiculture.
2) Observe the pH of household products and food products.
3) Understand how these products could change the conditions of the Habitat.
4) Apply this understanding to the health of the Habitat.
5) Make connections between pH and other conditions.
6) Observe how an extreme pH in one area of the Habitat can affect other sections.

PDE Standards

<u>Science and Technology</u>
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
<u>Environment and Ecology</u>
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
<u>Math</u>
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

CBL2 and pH sensor
Plant pH meter

Introduction

A plant pH sensor is good for this experiment since it requires less moisture than a Vernier pH sensor does. The Vernier pH sensor needs to be submerged in very wet vermicompost; usually the water content needed for this sensor would be too high for a healthy Habitat. This requires that students add a few grams of vermicompost to a few mL of distilled water. Usually an extreme condition (pH < 5 or > 8) of the vermicompost indicates rotting, uneaten, and/or excess garbage or dying or dead worms. The real value of the pH measurements is that any rapid changes in pH indicate something unusual. If rapid changes in pH conditions can be observed early and corrected, the worms will be fine. However, it may take several weeks for the vermicompost to return to optimum conditions naturally. Refrain from adding any chemicals to change the pH. A few drops of Universal pH indicator placed in a few grams of vermicompost diluted with a few mL of distilled water can also be used to determine the pH.

Strategies

The best method to introduce pH to students is to select a number of household products: soaps, cleaners, etc, and have students check the pH (hydrogen or hydroxide ions do not need to be introduced). Next have students check the pH of the individual food products added to the Habitat. If students observe and record the pH values of the food products added, they should observe the relationship between changes in pH and food products added, if any. The changes may not occur in the section where the food was added.

Procedure

1) Place the plant pH sensor into selected sections of the vermicompost to a depth of 2 or 3 cm. This assumes students have divided the surface into distinct areas for feeding and the feedings are alternated. **OR**
2) Collect several samples of vermicompost and place them in separate test tubes.
3) Add a small portion of distilled water; just enough to cover the bottom portion of the Vernier pH sensor. Record the pH in the journal and Data Table 1.
4) Record the average pH values from steps 1 or 2 and 3 in all Data Tables for other activities that require these measurements.

Expectations

The students should be able to:

1) collect pH data and record it accurately.
2) appreciate the need for correct pH ranges.
3) make connections between certain food and rapid pH changes in a specific section of the vermicompost.
4) observe that the pH of one section will effect nearby sections, though to a lesser degree.

Data Table 1 *(Typical Table)* **pH Values**

Sections	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Average**
Date	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**

Activity 13

Worm Behavior

Rationale: The usual species of worms used in vermiculture are considered to be phototropic, that is, they move towards light = positive (+) phototropism or move away from light = negative (-) phototropism. Vermiculture worms move away from BRIGHT light, but may be attracted to dim light. To what extent is the brightness related to the movement of the worms?

Objectives

1) Design an experiment that addresses worms' movement towards light.
2) Determine the effects, if any, of light on the worms.
3) Determine the effect of light intensity on the worms.

PDE Standards

Science and Technology
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
Environment and Ecology
4.1.7. A,B,C
4.2.7. A,C

Materials

CBL2 and light sensor
TI 83/84
Computer
Graphical Analysis
Ring stand
Test tube clamp

Introduction

If worms are removed from the vermicompost and placed on top of a flat pile of vermicompost, they dive for cover. The students will observe this trait quite quickly – but what is the reason? The worms may be diving for cover for various reasons. The students will need to be coached to devise an experiment to determine the variable(s) that causes this effect.

Strategies

For any inquiry approach to work successfully, the student must observe the behavior for a sufficient period of time. To have students come to class and be expected to develop questions to study, without a large number of observations, is counterproductive. If this Activity is done as a true inquiry approach, the students need to have made and recorded several hours (total for class) of observations. The journal entries from the very first day can be used to record these observations. After the appropriate amount of hours of observations as many reasons as possible for this behavior can be suggested. This activity can be done as the very first experiment. If it done as one of the first activities it will have to be planned out for the students and cannot be used as a student developed strategy. If this activity is used later in the program it can be used as a true inquiry approach to a study. It will be assumed that worms move away from light because a light was used to collect and sort the worms. However, it will need to be shown the assumptions are in fact, true. All the variables that may be related to this behavior should be listed and experiments designed to determine which of the possible variables cause the effect.

Procedure

1) Break into groups of three or four students.
2) In each group make a list of the possible causes.
3) Each group makes a presentation.
4) The class comes to a consensus.
5) Each group selects the variable(s) to be studied by the group.

Expectations

The students should be able to:

1) make appropriate observations.
2) decide what observations are needed for a specific behavior.
3) select appropriate potential causes (variables).
4) design several drafts of possible methods to test for cause and effect.
5) design an appropriate experiment with coaching.
6) design an appropriate data table.

Data Table 1 *(Typical Table)*

Variable	Light	Moisture	Temperature	Noise	?	?
Toward (+)						
Neutral						
Away (-)						

Activity 14

Degree of Avoidance to White Light

Rationale: It was determined that worms avoid bright white light in Activity 12. It is also important to know if the brightness has an effect on the worms. The students, with the aid of a light sensor, can determine if the worms react to differing intensities of light.

Objectives

1) Determine the effect of intensity of white light on worms' avoidance behavior.
2) Determine the effect of distance on white light intensity.
3) Set up an experiment to determine the effect of light intensity on worm avoidance behavior.

PDE Standards

Science and Technology
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F.
3.4.7. B
3.6.7. A,B
3.7.7. A,B,C,D
Environment and Ecology
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
Math
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

CBL2
TI 83/84
Graphical Analysis
Computer
Ring stand (2)
Stopwatch
White LED
Camera light meter
Vernier light sensor
Ruler
Test tube clamp (2)

Introduction

To be able to accurately determine the effect of light intensity, students need to understand the inverse effect of intensity and distance. The actual effect is called the inverse square law. If an intensity light reading is taken of a light bulb at a distance of 10.0 cm and then the sensor is moved to 20.0 cm, the intensity will decrease by a factor of 1/4 the original. If the sensor is then moved from the original 10.0 cm to 30.0 cm, the intensity of the light will decrease by a factor of 1/9 of the original. If the distance is changed to 40.0 cm, 4 times the original distance of 10.0 cm, the intensity will decrease to 1/16 of the original.

1) double (2x) the distance and the intensity will decrease by the inverse of 2 = ½; $(½)^2$ = ¼ as intense.
2) Triple the distance (3x) and the intensity will decrease by the inverse of 3 = ⅓; $(⅓)^2$ = 1/9 as intense.
3) Quadruple the distance (4x) and the intensity will decrease by the inverse of 4 = ¼; $(¼)^2$ = 1/16 as intense.

Strategies

The students should set up the light bulb in a darkened room and measure the light intensity at various distances and record the light intensity. If the distances and the intensities are measured by several groups and averaged, the results should approximate the inverse square law rather well. This will not work with a flashlight. That light is directed out through the lens from the mirror behind the bulb in a compacted stream and does not obey the inverse square law in the same way. If the diameter of the spot of light doubles, then the intensity obeys the inverse square law.

Procedure
Inverse square law

1) Darken the room or work in a very dark place.
2) Set up the light bulb on a ring stand.
3) Set up the light sensor on a ring stand.
4) The light bulb and sensor should be at the same height.
5) Measure (to the nearest tenth of a cm) the distance from the LED to the front of the sensor.
6) Press the APPS button and select the DataMate application. Select and setup the light sensor for "events with entry" or read the intensity in the upper right corner of the TI screen.
7) Record the distance and intensity in Data Table 1.

Optional

8) Enter the distances in List 1. Overwrite any values that are in List 1.
9) Perform a pwr (power) regression on the data. Power refers to the square (2^{nd} power) of the value.

Procedure
Light intensity

1) Use the original distance from the previous Data Table 1 and record the distance in Data Table 2.
2) Collect 4 mature worms.
3) Place a fluffed up sample of vermicompost on a white piece of paper.
4) Place the worms on the vermicompost and turn on the light at the same time.

5) Record the time (seconds) for four worms to bury themselves.
6) Record the light intensity at this distance.
7) Use the appropriate distances from the previous Data Table1 for the following steps.
8) Double the original distance. Record the burying time with the same worms.
9) Record the light intensity at this distance.
10) Triple the original distance and record the burying time with the same worms.
11) Record the light intensity at this distance.
12) Quadruple the original distance and record the burying time with the same worms.
13) Record the light intensity at this distance.
14) Enter the burying times in List 1 and the corresponding light intensities in List 2.
15) Perform a linear regression on these data.
16) The slope corresponds to the rate at which the worms bury themselves with respect to the intensity (inverse relationship - negative slope).

Expectations
The students should be able to:
1) set up the inverse square law experiment.
2) collect the appropriate inverse square law data accurately.
3) analyze the data.
4) set up the worm light avoidance experiment.
5) collect the appropriate worm avoidance data.
6) analyze the data.
7) draw appropriate conclusions from the appropriate results.

Data Table 1 **Light Intensity vs. Distance (darkened room)**

Distance(cm)				
Intensity	XXX	XXX	XXX	XXX
Group 1				
Group 2				
Group 3				
Group 4				
Group 5				
Average				

Data Table 1a **Light Intensity vs. Distance (dim room)**

Distance(cm)				
Intensity	LED – room = real Intensity	LED – room = real Intensity	LED – room = real Intensity	LED – room = real Intensity
Group 1				
Group 2				
Group 3				
Group 4				
Group 5				
Average				

For a dimly lit room take the intensity reading with the light sensor in the dimly lit room and subtract that reading from all subsequent intensity measurements and record the values in Data Table 1a (alternate).

1. What relationship is observed between the intensity and distance?

Data Table 2 **Time vs. Intensity**

Intensity (ave)				
Time (sec)	XXXX	XXXX	XXXX	XXXX
Group 1				
Group 2				
Group3				
Group 4				
Group 5				
Averages				

1. What relationship is observed between the intensity and distance?
2. What relationship is observed between the intensity and burying time?

Activity 15

Worm Behavior with Light

Rationale: White light will have a negative effect on worm behavior and it is possible that worms may not react to different colors of light. Counting and sorting worms can be frustrating and if the worms do not avoid one or more colors of light that result could be used to the students' advantages.

Objective

1) Determine if different colors of light effect worms differently.
2) Determine if one color has little or no effect on the worms.
3) Determine one or more methods to determine the color with the least negative effect.

PDE Standards

Science and Technology

3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.4.7. B
3.6.7. A,B
3.7.7. A,B,C,D

Environment and Ecology

4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C

Math

2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials (depend on students experiments)

CBL2
TI 83/84
Graphical Analysis
Computer
Stopwatch
Various colored LEDs OR
Flashlights and colored cellophane
Light sensor (used camera shop)
Vernier light sensor

Introduction

The students will have determined that worms avoid bright white light in Activity 11. To some extent, moisture should have shown a positive reaction, also. However, in this activity, the focus is on the color(s) of light that have the least effect. The commonly used worms for vermiculture are most sensitive to blue light and least sensitive to red light.

Strategies

The students should be able to set up the experiment for this activity without a lot of teacher assistance. However, it is a good idea to ask the students if they feel the intensity is the same for each LED or cellophane covered light beam. Or does the intensity affect the results in this activity? The students should decide that it does and they should be able to set up the experiment so the intensities are the same for each color trial.

Procedure

1) Set up the equipment for this activity.
2) Set up the CBL2 and have the light sensor ready to make an intensity measurement. Use the dimmest LED placed at an appropriate distance.
3) Record the intensity in the journal and Data Table 1.
4) Place four mature worms on a flat pile of vermicompost and turn on the light at the same time.
5) Record the burying time.
6) Repeat two more trials.
7) Record burying times.
8) Replace the original LED with an LED of a different color.
9) Adjust the distance to obtain the same intensity as the first LED.
10) Repeat two more trials.
11) Record the burying times.
12) Repeat with all other colors of LEDs.
13) Record all measurements in the journal and in Data Table 1.
14) Draw conclusions from the results.

Expectations

The students should be able to:

1) set up the equipment and discern what data are needed.
2) use a calculator to perform basic calculations.
3) determine which color of light has the least avoidance effect.
4) determine which color of light has the greatest avoidance effect.

Table Data 1 for Group___

Times (s)	1st	2d	3rd	Ave	1st	2nd	3rd	Ave	1st	2nd	3rd	Ave	1st	2nd	3rd	Ave
Violet																
Blue																
Green																
Orange																
Yellow																
Red																

Data Table 1 ***(Typical Table)*** **Time vs. Color**

Time (s) (Ave)	Violet	Blue	Green	Orange	Yellow	Red
Group 1						
Group 2						
Group 3						
Group 4						
Group 5						
Average						

Activity 16

Response to Light by Age

Rationale: From previous Activities 12, 13, and 14, the phototropic response to light was determined by intensity and by color. A question that remains: Does the response change with age of the worm? If the response is learned, then the older the worm is the quicker it will respond to bright light.

Objectives

1) Set up an experiment for response to light by age of the worm.
2) Use the previous age classifications to collect data for this question.
3) Determine if there is a relationship between age and response time.

PDE Standards

<u>Science and Technology</u>
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.4.7. B
3.6.7. A,B
3.7.7. A,B,C,D
<u>Environment and Ecology</u>
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
<u>Math</u>
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. FG,H,I,J
2.11.8. A,B

Materials

Worms sorted by age
Small polystyrene cups with lids
Stopwatch
Ring stands
Test tube clamps

Introduction

One of the more interesting aspects of worm behavior is whether certain behaviors are learned or instinctual. *Planaria* can be taught to navigate a maze in search of food. The search for food is instinctual, but the navigation of the maze is a learned behavior. Do vermiculture worms learn to avoid light or is it instinctual?

Strategies

The students should quickly design a good experiment to determine the effect of age on the avoidance response to light. The most difficult part of this experiment is finding very young worms and not hurting them.

Procedure

1) Set up the equipment to measure burying times.
2) Sort worms into the three classifications (hatchlings, juvenile, mature).
3) Collect about a ½ dozen of each.
4) Place 4 worms on a flat pile of vermicompost.
5) Record the burying time in the journal and Data Table 1.
6) Compare the class averages for each age classification.
7) Draw conclusions from the results.

Expectations

The students should be able to:

1) set up the equipment quickly and accurately.
2) collect burying times with a minimum of teacher assistance.
3) determine if there is an age vs. burying time relationship.
4) record measurements for trials in the journal and record the averages in Data Table 1.

Data Table #1

Time (s)	Hatchlings	Juvenile	Mature	Relationship*
Group 1 (ave)				
Group 2 (ave)				
Group 3 (ave)				
Group 4 (ave)				
Group 5 (ave)				
Averages(1- 5)				

*** Determine a small whole number relationship (Ex. 31s, 39s, 35s) = 1:1:1 or 40s, 100, 44 = 2:5:2)**

Activity 17

Mass of Input vs. Mass of Output

Rationale: The amount of foodstuffs added to the Habitat compared to the mass of runoff water and the increase in the mass of the worms should be related to the health of the Habitat. These data can be used to determine the efficiency of the system.

Objectives

1) Enter data from Data Table 1 and 2 from Activity 1 in the graphing calculator or Graphical Analysis.
2) Decide what variables are to be compared.
3) Decide what causes and effects are present, if any.
4) Evaluate the variable data collected and decide if the appropriate variables are being measured.
5) Make changes, if necessary.

PDE Standards

<u>Science and Technology</u>
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
<u>Environment and Ecology</u>
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
<u>Math</u>
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. AB,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

Data from Activity 1
TI 83/84
Computer
Graphical Analysis (software)

Introduction

The bedding was weighed and 3 times its mass equals the amount of water added to the bedding. This became the original mass of the future vermicompost. Foodstuffs were added and the average amount of water was generally considered to be about 70% of the mass of the foodstuffs. In a healthy Habitat, the excess water will drain off at the bottom of the bin. Some water evaporates and therefore cannot be measured. The worms will grow, reproduce, and produce more worms. As the Habitat matures and weekly or bi weekly mass data are collected and analyzed, patterns will begin to appear. If the appropriate amount of foodstuffs is added, a relationship will begin to develop between the input amounts and the growth of the worms and excess water that is present.

Strategies

This activity will require more guidance/coaching than more recent activities. The relationships developed in this Activity will enhance the learning and understanding by the students of the micro ecosystem developed in the Habitat. The maximum and minimum of the measurements will give the students some idea of the complexity of the Habitat. The previous activities have given the students confidence in their abilities to solve ecological problems.

Procedure

1) Groups observe Data Table 1 and 2 from Activity 1 and propose a method of analysis.
2) Groups design an appropriate analysis of data sets.
3) Groups present a data analysis design to the class.
4) Students reflect on suggestions and redesign the method, if appropriate.
5) Groups' data analysis design is given to the teacher for final approval.
6) Conclusions are drawn from the results.

Expectations

The students should be able to:

1) design appropriate data analysis methods.
2) determine the quantitative values.
3) link the quantitative aspects of the Habitat with the qualitative conditions.

Data Table 1

Date	Volume of vermi-compost*	Mass of worms	Mass of vermi-compost	Mass of food stuffs	Mass of water added	Mass of excess H_2O	Net gain or loss
							XXXX

*Not used in final “Net gain or loss”

Activity 18

Analysis of Foodstuffs

Rationale: The mass of foodstuff added and the chemical characteristics will help determine the effects of the foodstuffs on the Habitat.

Objectives

1) Determine the mass of the groups of foodstuffs.
2) Compare the mass of each food group and its chemical properties to the chemical changes of the Habitat.

PDE Standards

<u>Science and Technology</u>
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
<u>Environment and Ecology</u>
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C

Materials

Data Tables
TI 83/84
Graphical Analysis
Computer
Mini bins*
Mature worms

* Mini bins can be made from large plastic containers (1 - 2 liters). Add clean wet bedding to the container. Punch holes in the bottom for excess water to drain. Punch larger holes in the side for air to enter (similar to the class habitat) and holes in the lid. These can be used with other group activities.

Introduction

The mass of the foodstuffs added will add considerable water to the Habitat. This amount will be an approximation, but needs to be included in the calculations. The shredded newsprint is fairly self regulating in terms of its water content; that is, excess water can drain off. However, if it is observed that large amounts of high water content foodstuffs have been added in recent weeks, drainage should also be observed. The pH of the foodstuffs should also be recorded to compare to any changes in the pH of the runoff water and any changes in the pH of the vermicompost.

Strategies

This will be one of the easiest activities for the students, requiring very little coaching. The data have been collected on a regular basis and the students have had sufficient practice with discovering existing relationships. The most important coaching aspect is to guide students to correct conclusions from appropriate results.

Considerable coaching will be needed with the use of an approximate value. Final values can include a range of the minimum and maximum amount of water added to the Habitat. At this time in the maintenance of the Habitat, assumptions may be made that are not appropriate. Students will need to do research to obtain the pH of each group of foodstuffs and the water content in order to complete Data Table 1.

Procedure

1) Enter the masses, pH, and % water content values in Data Table 1.
2) Determine the approximate (range) mass of water added to the Habitat.
3) Draw conclusions from the results.

Expectations

The students should be able to:

1) condense data from Data Table 1 and 2 in Activity 1 to Data Table 1 in this activity.
2) find results and draw appropriate conclusions.
3) work with an approximate value in a Data Table.

Data Table 1 *(Typical Table)* **Mass of Foodstuffs Added**

Date	Fruits	Gr. Leafy Vegetables	Solid vegetables	Cereals	Legumes	Tubers

Data Table 2 *(Typical Table)* **Water Content of Foodstuffs Added***

Date	Fruits	Gr. Leafy Vegetables	Solid vegetables	Cereals	Legumes	Tubers	Mass of added water

* Mass of foodstuff in the food group times the % water content = mass of water added

Activity 19

Castings

Rationale: The amount of castings (excreta) is an important measure of the overall health of the Habitat. The mass of the castings is also related to the mass and age of the worms present.

Objectives

1) Determine if there are any relationships established between the mass of the castings and the other variables.
2) Collect castings in a specific portion of the Habitat.
3) Estimate the total mass of castings in the vermicompost.

PDE Standards

Science and Technology
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
Environment and Ecology
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
Math
2.1.8. A,B
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

TI 83/84
Plastic cups
Tweezers

Introduction

The mass of the castings can be measured in several small samples removed from the vermicompost. After the worms are removed, castings and cocoons are visible within the vermicompost. These castings will be a valuable source of enrichment for plants (Wisconsin Fast Plants®) used in later activities. The castings are a result of the worms' digestive processes and the castings are nutrient rich.

Strategies

This is an activity designed for students to collect castings in several small samples of the compost, weigh the castings, and then estimate the total mass of the castings in the Habitat. The students must look at 10 or more 100 mL samples of the vermicompost. These samples must be representative of the whole system. The worms are separated from the vermicompost. The worms and cocoons can also be counted/weighed and these data can be used in future activities. For this immediate activity, only the mass of the castings will be used to predict the total mass of the castings. Students should collect and weigh the castings from the selected samples and determine if they believe the samples are representative of the whole. The castings will be found mostly in the upper strata of the bin, but not exclusively. This depends on the methods of maintenance and bin size. By taking several samples from several specific areas, these representative samples can then be used to predict the total mass of castings. The sections that are used for alternating feedings can be used as well as several layers. The usual method is to have six feeding areas and 3 strata. That will give a total of 18, 3 dimensional sections, similar to rooms in an apartment house. If a 100 mL sample is carefully collected from half of these sections good results will be obtained. Nine or ten 100 mL samples (ca. liter) will be a small, but representative of the entire vermicompost. After the students have weighed the castings in the samples and averaged the values, the total mass of the castings can be predicted mathematically. The number, age, mass of the worms, and the number and mass of the cocoons can also be recorded for future activities and used to predict the total mass and numbers of worms compared to the actual hand-collected values.

Procedure

1) Decide on the sections to be sampled.
2) Carefully obtain about a 100 mL sample. Record the actual volume in the journal and Data Table 1.
3) Count the worms and return them to the vermicompost.
4) Count the cocoons and leave them in the sample.
5) Remove the castings, weigh, and record the mass.
6) Repeat with 8 or 9 more samples.
7) Return all the samples to the vermicompost and mix them carefully into the top stratum.
8) Complete Data Table 1.
9) Draw conclusions from the results.

Expectations

The students should be able to:

1) determine a reasonable set of sample locations.
2) collect and weigh the castings from the selected samples.
3) collect and record data for the worms and cocoons.
4) use the TI 83/84 to predict the total mass of the castings.

Data Table 1

Sample	Volume	Castings
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
Average		

Data Table 2

Volume Bin	Volume Average	Castings Average	Total castings*

* The total is the result of the average volume of samples *divided* into the total volume of vermicompost *times* the average mass of the castings.

Data Table 3 (optional)

Sample	Volume	cocoons #	Worm #*			Worms mass		
XXXX	XXXX	XXXX	Ha	Ju	Ma	Ha	Ju	Ma
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
Average								
Total								

*Ha = hatchlings, Ju = juvenile, Ma = mature

Activity 20

Predictions vs. Actual

Rationale: The counting/weighing to obtain the actual values for the worms, cocoons, and castings is a tedious and potentially harmful activity. To be able to take samples and accurately predict values is an important part of ecological research.

Objectives

1) Use collected sample data to predict totals.
2) Compare predicted values to actual values.

PDE Standards

Science and Technology
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
Environment and Ecology
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
Math
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

Data tables
TI 83/84
Graphical Analysis (software)
Computer

Introduction

One of the most important aspects of science research is to be able to predict future values. This is especially true in situations when the collection of actual measurements is extremely difficult, might perturb the ecological system, or might be too tedious to get accurate values. Certainly two of the above constraints apply to this Habitat. The actual values will be collected one time to compare to predicted values. The amount of castings, worms, and cocoons are important aspects of the vermiculture and at some time the excess castings and worms must be removed. This is the time to do a complete census.

Strategies

This activity will be very tedious and requires a careful selection of the time when it is done. The best time to do this activity is when the vermiculture needs to be thinned. Removing the excess worms and castings is necessary when the vermiculture matures. As the castings are removed, they can be weighed, and the worms can be sorted, weighed, counted, and recorded. Additional shredded and moistened (three water to one newsprint by mass) newsprint can be added. After the castings have been removed and weighed, the worms sorted, counted and weighed, and the cocoons counted, the values can be compared to the predicted.

Procedure

1) Complete the following Data Table 1.
2) Compare the predicted values to the actual values.
3) Determine the percent error.
4) Draw conclusions from the results.

Composite Data Table

Variable	Castings	Hatchlings		Juvenile		Mature		Cocoons
XXXX	XXXX	#	Mass	#	Mass	#	Mass	XXXX
Predicted								
Actual								
Difference								
% error								

Activity 21

Determination of Food Choice by Age

Rationale: The assumption could be made that all ages of worms prefer all types of food. This activity will take one feeding cycle and the worms need to be observed, sorted, and counted several times a day for the full feeding cycle.

Objectives

1) Set up an experiment that has actual implications for the vermiculture.
2) Analyze the data collected.
3) Calculate a food group ratio for hatchlings, juvenile, and mature worms.
4) Make recommendations based on the analysis.

PDE Standards

Science and Technology
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
Environment and Ecology
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
Math
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

Habitat
Counting boards
Sorting cups
TI 83/84

Introduction

The quantity of different food groups may cause an observable effect on the development of the worms or the reproductive process. It is important to have the best ratio of foodstuffs for the worms. If only sexually mature worms were harvested and placed in breeding bins, the best ratio of the food groups would ensure the best reproduction, largest number of cocoons, the highest number of worms per cocoon, and the best rate of live hatchings from each cocoon. On the other hand, the type and quantity of the food might make no difference.

Strategies

The overarching concept of this activity is that students realize a very useful set of data are being collected. These data can be useful for larger practitioners of vermiculture. The design of the activity is very straight forward and is focused on a very practical aspect of vermiculture. Very little coaching should be required.

Procedure

1) Mix the top two strata of the vermicompost very carefully.
2) Remove any unconsumed food.
3) Place a reasonable sized piece of each of the food groups in specific locations on the surface of the vermicompost. Leave the center free.
4) Replace the lid and wait for a few hours.
5) Open the lid and quickly collect, sort, and count the worms according to the age groups.
6) Place all the worms together and replace them in the center of the surface of the vermicompost.
7) Repeat this sampling process once or twice a day for 10 collections.
8) Replenish any consumed food groups after each sampling.
9) Record all data in the journal and Data Table 1.
10) Draw conclusions from the results.

Expectations

The students should be able to:

1) collect, sort, and count the worms without coaching.
2) complete the Data Table.
3) draw conclusions from the results calculated in the Data Table.
4) make predictions of the food group for each age group.

Data Table 1 *(Typical Table)* **Number of Worms in Each Food Group**

Time	Fruits			Gr. Leafy Vegetables			Solid vegetables			Cereals			Legumes			Tubers		
	H	J	M	H	J	M	H	J	M	H	J	M	H	J	M	H	J	M
Total																		
Ave																		
Ratio*																		

* Small whole number ratio

Activity 22

Analysis of Run-off – Leachate or Tea

Rationale: The run-off water at the bottom of the bin is an important aspect of the vermiculture. One of the scientific names best ascribed to this liquid is leachate. The traditional name is tea, because of its tea-like appearance.

Objectives

1) Determine the pH of the leachate.
2) Determine the specific ion concentrations of the leachate.

PDE Standards

<u>Science and Technology</u>
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
<u>Environment and Ecology</u>
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
<u>Math</u>
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

CBL2
TI 83/84
pH sensor
50-mL beakers (20)
Distilled water
Vernier: specific ion sensors - chloride, nitrate, calcium, ammonia (*aq*) OR
Aquarium test kits: nitrate, nitrite, ammonia (*aq*), carbonate hardness, phosphate, and copper

Introduction

The chemical characteristics of the leachate are important. *E. fetida* and *E. andreii* are being considered for possible rehabilitation of contaminated soils. Aquarium test kits can be used in place of the CBL2, TI 83/84, and Vernier sensors. The Vernier sensors measure in continuous mg/L, whereas the aquarium kits will have limited ranges and read in various units. Either one will work for this activity. The chemical characteristics of the leachate are a view of the various ions that are available from certain foodstuffs and how well the worms tolerate these chemicals. One of the more popular vermiculture research areas focuses on the tolerance of salty soils by the worms. These are soils that have been contaminated with surface ocean water or the invasion of underground fresh water aquifers by salt water.

Strategies

As with all of the chemical activities, the students may need a little more coaching than usual. However, if they have approached the previous activities carefully and in a scholarly manner, this activity will be evidence of their laboratory skills. It is reasonable to write the chemical formula in English, but the introduction of chemical symbols is good pedagogy. Unbalanced chemical equations will suffice. Samples of the leachate should be tested on a regular basis and measurements recorded in the journal and in Data Table 1. Because the aquarium test kits and the Vernier sensors each test for different ions (nitrate and ammonia (*aq*) in common), the best method is to use both. The Vernier sensors report the measurement digitally and the aquarium test kits use a color reference chart.

Procedure

1) Collect the leachate.
2) If no leachate is present, make enough leachate for the class. Pour distilled water on top of the vermicompost. The water will run through and leach out the soluble particles. The leachate can be collected at the bottom of the bin.
3) Place 10 mL samples (aliquots) in as many 50-mL beakers as needed for duplicate tests.
4) Test each sample for a specific ion (use one beaker for each measurement).
5) Use either the Vernier sensors or the aquarium test kits or both if available.
6) Use the DataMate application.
7) Set up the CBL2 for each of the sensors by following the on-screen directions.
8) Set up the aquarium test kits and follow the specific directions for each test, using the appropriate color reference guide.
9) Record the measurements in the journal and Data Table 1.
10) Draw conclusions from the results.

Data Table 1 All values are reported in ppm (mg/L = ppm)

Date	**pH**	**Cl^-**	**NO_3^-**	**Ca^{2+}**	**PO_4^{3-}**	**NO_2^-**	**NH_3(*aq*)**

Activity 23

Tolerance to Sodium Chloride by Weight

Rationale: Recently storms have caused fresh water soils to become contaminated with sea water. A recent study by M. Kerr and A.J Stewart in the *Journal of Undergraduate Research,* pp 21 -25*,* Volume III*,* 2003*,* completed a very straight forward study of salt water and *E. fetida*. The following activity is an adaptation of that study.

Objectives

1) Determine if the worms lose weight in vermicompost laced with various percentages of NaCl.
2) Design an experiment to study the tolerance of the worms to NaCl.

PDE Standards

<u>Science and Technology</u>
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.5.7. D
3.6.7. A,B
3.7.7. A,B,C,D
<u>Environment and Ecology</u>
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
<u>Math</u>
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

Saltwater aquarium test kit
NaCl (table salt)
100-mL graduated cylinders (2)
I-L plastic containers (mini bins)
Balance
Plastic spoon
CBL2
Vernier salinity sensor
TI 83/84
I-qt food containers
Good potting soil at least 50% peat

Introduction

Contaminated soils are in desperate need of remediation. Rains can dilute the NaCl and leach it from the soil slowly, depending on the amount of rain. If worms can tolerate salty soils, then salt tolerant worms could help remediate the soils. This experiment will focus on the tolerance of worms to various NaCl concentrations by weight.

Strategies

As with previous rigorous inquiry activities introducing a new variable, considerable coaching will be needed. There are few, if any articles available at the middle school level for students to read. A review/discussion of human tolerance to NaCl water will be needed. A student led discussion needs to take place of people surviving at sea for extended periods of time sipping seawater, thirstiness after eating high salt content foods, the bitter taste/thirst of sea water, etc. Students can be coached to realize that freshwater fish cannot be placed in the ocean and vice versus (with few exceptions, salmon and eastern freshwater eels). Students can begin to brain storm weeks prior to introducing this Activity. Activity 23 will address weight management. Mature worms will be placed in soils of various NaCl concentrations, weighed before, and weighed several days later. A review of making solutions is necessary and a discussion of converting ppm to ppt (‰) to pph (%). Coaching is required for the experimental design.

Procedure

1) Determine the size and type of test containers.
2) Determine the amount of NaCl to add to 1.0 L of distilled water.
3) Determine what types of soils to use.
4) Make up solutions, approximately (0, 2, 4, 8, and 16% by weight).
5) Punch holes in the bottom of the plastic container to allow leachate to escape.
6) Punch several holes on the sides for air to enter. These holes must all be too small for mature worms to escape.
7) Punch larger holes in the lid for air to enter.
8) Add about 500 mL of potting soil to each of 5 containers (new Habitats).
9) Add 50 mL of the 1% solution to the container marked 1%.
10) The 0% will become the control.
11) Repeat with each solution and each appropriate container. Let stand for a day.
12) Add about 50 mL of distilled water; the soil should be just damp to the touch.
13) Collect 25 mature (with obvious clitellum) worms.
14) Place all the worms in a 1-L container overnight to allow them to void their guts.
15) Store this container in the habitat if possible; at least in a safe dark place. Holes must be punched in the lid.
16) Weigh sets of five worms and record the weight in the journal and Data Table 1.
17) Place each set of worms in one of the five containers.
18) Carefully record the correct set of worms and container.
19) Add an appropriate amount of food. Keep a continuous amount of fresh food.
20) Store in an empty worm bin.

21) Check the containers each day; stop the trial if the worms are in obvious distress (none should be).
22) After two weeks, remove the worms and place them in empty individual plastic containers by sets to void.
23) Weigh the voided worms by sets. Record the data in the journal and Data Table 1.
24) Complete Data Table 1.
25) Draw conclusions from the results.
26) The mass loss or gain of the 0% control must be subtracted from the difference in mass. Use – or + values.

Procedure Optional
1) Press the APPS button. Select Datamate
2) Set up the salinity sensor.
3) Check the salinity of the different solutions. Record the data in the journal and the Optional Data Table 1.
4) Repeat Step 3 with the salt water aquarium test kit.

Expectations
The students should be able to:
1) design a reasonable experiment.
2) design the set up.
3) set up the experiment and collect the appropriate data.
4) record the measurements and complete Data Table 1.
5) understand the connection between tolerance and weight loss.

Data Table 1

Concentration (%)	Intitial mass of worms	Final mass of worms	Difference In mass	Loss (-) or Gain (+)	Corrected Mass
0					XXXX
2					
4					
8					
16					

Optional Data Table **Comparison of the solutions' % concentration**

% concentration	Prepared %	Salinity Sensor	+/- difference
0			
2			
4			
8			
16			

Activity 24

Age Tolerance to Sodium Chloride

Rationale: Recently storms have caused fresh water soils to become contaminated with sea water. A recent study by M. Kerr and A.J Stewart in the *Journal of Undergraduate Research,* pp 21 -25, Volume III, 2003*,* completed a very straight forward study of salt water and *E. fetida*. The following activity is an adaptation of that study. The tolerance to salt by differing ages of worms is an important aspect of remediation of NaCl contaminated soils.

Objectives

1) Determine if worms of various ages lose weight in vermicompost laced with various percentages of NaCl.
2) Design an experiment to study the tolerance of worms to NaCl by age.

PDE Standards

Science and Technology

3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.5.7. D
3.6.7. A,B
3.7.7. A,B,C,D

Environment and Ecology

4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C

Math

2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

Saltwater aquarium test kit
NaCl (table salt)
100-mL graduated cylinders (2)
I-L plastic containers (mini bins)
Balance
Plastic spoon
CBL2
Vernier salinity sensor
TI 83/84
I-qt food containers
Good potting soil at least 50% peat

Introduction

Contaminated soils are in desperate need of remediation. Rains can dilute the NaCl and leach it from the soil slowly, depending on the amount of rain. If worms can tolerate salty soils, then salt tolerant worms could help remediate the soils. This study will determine the tolerance of hatchlings, juveniles, and sexually mature worms to various NaCl laced soils.

Strategies

As with previous rigorous inquiry activities introducing a new variable, considerable coaching will be needed. There are few if any articles available at the middle school level for students to read. A review/discussion of the tolerance of humans to NaCl water will be needed. A student led discussion needs to take place of people surviving at sea for extended periods of time sipping seawater, thirstiness after eating high salt content foods, the bitter taste/thirst of sea water, etc. Students can be coached to realize that freshwater fish cannot be placed in the ocean and vice versus (with few exceptions, salmon and eastern freshwater eels). Students can begin to brain storm weeks prior to introducing this Activity. Activity 24 will address weight management of hatchlings, juveniles, and mature worms. These three groups of worms will be placed in identical soils of various NaCl concentrations, weighed before, and weighed after several days. A review of making solutions is necessary and a discussion of converting ppm to ppt (‰) to pph (%). Coaching is required for this experimental design.

Procedure

1) Determine the size and type of test containers.
2) Determine the amount of NaCl to add to 1.0 L of distilled water.
3) Determine what types of soils to use.
4) Make up solutions, approximately (0, 2, 4, 8, and 16% by weight).
5) Punch holes in the bottom of the plastic container to allow leachate to escape.
6) Punch several holes on the sides for air to enter. These holes must all be too small for mature worms to escape.
7) Punch larger holes in the lid for air to enter.
8) Add about 500 mL of potting soil to each of the 5 containers (new Habitats).
9) Add 50 mL of the 1% solution to the container marked 1%.
10) The 0% will become the control.
11) Repeat with each solution and each appropriate container. Let them stand for a day.
12) Add about 50 mL of distilled water; the soil should be just damp to touch.
13) Collect 25 mature (with obvious clitellum) worms.
14) Collect 25 juveniles, >4 cm, but without clitellum.
15) Collect 25 hatchlings, < 4 cm.
16) Place the mature worms in a 1-L container overnight to allow them to void their guts.
17) Repeat with the juveniles and hatchlings.
18) Store these containers in the habitat if possible, at least in a safe dark place. Holes must be punched in the lid.

19) Weigh sets of five mature worms; record the weight in the journal and Data Table 1.
20) Weigh sets of five juvenile worms; record the weight in the journal and Data Table 1.
21) Weigh sets of five hatchling worms; record the weight in the journal and Data Table 1.
22) Place each set of hatchlings in one of the five containers.
23) Place each set of juveniles in one of the five containers.
24) Place each set of mature worms in one of the five containers.
25) Carefully record the correct set of worms and container.
26) Add an appropriate amount of food. Provide a continuous amount of fresh food.
27) Store in an empty worm bin.
28) Check the containers each day. Stop any trial if the worms are in obvious distress (none should be).
27) After two weeks remove the worms and place them in empty individual plastic containers by sets and age to void.
28) Weigh voided worms by sets and ages. Record in the journal and Data Table 1, 2, or 3.
29) Complete Data Tables 1, 2 and 3.
30) Draw conclusions from the results.
31) The mass lost or gained of the 0% control must be subtracted from the difference in mass. Use – or + values.

Procedure Optional

1) Press the APPS button; select Datamate.
2) Set up the salinity sensor.
3) Check the salinity of the different solutions. Record the data in the journal and Optional Data Table 1.
4) Repeat Step 3 with the salt water aquarium test kit.

Expectation

The students should be able to:

1) design a reasonable experiment.
2) design the set up.
3) set up the experiment and collect the appropriate data.
4) record the measurements and complete Data Table 1.
5) understand the connection between tolerance, age, and weight loss.

Data Table 1 **Hatchlings**

Concentration (%)	Initial mass of worms	Final mass of worms	Difference In mass	Loss (-) or Gain (+)	Corrected Mass
0					XXXX
2					
4					
8					
16					

Data Table 2 **Juveniles**

Concentration (%)	Initial mass of worms	Final mass of worms	Difference In mass	Loss (-) or Gain (+)	Corrected Mass
0					XXXX
2					
4					
8					
16					

Data Table 1 **Mature Worms**

Concentration (%)	Initial mass of worms	Final mass of worms	Difference In mass	Loss (-) or Gain (+)	Corrected Mass
0					XXXX
2					
4					
8					
16					

Optional Data Table **Comparison of the solutions' % concentration**

% concentration	Prepared %	Salinity Sensor	+/- difference
0			
2			
4			
8			
16			

Activity 25

Tolerance of Cocoons and Hatchlings to NaCl

Rationale: Recently storms have caused fresh water soils to become contaminated with sea water. A recent study by M. Kerr and A.J Stewart in the *Journal of Undergraduate Research*, pp 21 -25, Volume III, 2003, completed a very straight forward study of salt water and *E. fetida*. The following activity is an adaptation of that study.

Objectives

1) Design an experiment to study the tolerance of cocoons and hatchlings to NaCl.
2) Determine if cocoons hatch in vermicompost laced with various percentages of NaCl.
3) Determine if hatchlings survive.

PDE Standards

Science and Technology
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.5.7. D
3.6.7. A,B
3.7.7. A,B,C,D
Environment and Ecology
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
Math
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

Saltwater aquarium test kit
NaCl (table salt)
100-mL graduated cylinders (2)
I-L food containers (mini bins)
Plastic spoons
CBL2
Vernier salinity sensor
TI 83/84
Balance
Good potting soil, at least 50% peat

Introduction

Contaminated soils are in desperate need of remediation. Rains can dilute NaCl and leach it from the soil slowly, depending on the amount of rain. If worms can tolerate salty soils, then salt tolerant worms could help remediate the soils. This experiment will focus on the tolerance of cocoons to various NaCl concentrations.

Strategies

As with previous rigorous inquiry activities introducing a new variable, considerable coaching will be needed. There are few if any articles available at the middle school level for students to read. A review/discussion of the tolerance of humans to NaCl water will be needed. A student led discussion needs to take place of people surviving at sea for extended periods of time sipping seawater, thirstiness after eating high salt content foods, the bitter taste/thirst of sea water, etc. Students can be coached to the realization that freshwater fish cannot be placed in the ocean and vice versus (with few exceptions, salmon and eastern freshwater eels). Students can begin to brain storm weeks prior to introducing this Activity. Activity 25 will simply address the hatching of worms in cocoons placed in vermicompost of various NaCl concentrations. A review of making solutions is necessary and a discussion of converting ppm to ppt (‰) to pph (%). Coaching is required for this experimental design.

Procedure

1) Determine the size and type of test containers.
2) Determine the amount of NaCl to add to 1.0 L of distilled water.
3) Determine what types of soils to use.
4) Make up solutions, approximately (0, 2, 4, 8, and 16% by weight).
5) Punch larger holes in the lid for air to enter.
6) Add about 100 mL of aged and dry vermicompost to each of 5 containers. Be careful to have no worms or cocoons. Castings are fine.
7) Add 50 mL of the 1% solution to the container marked 1%.
8) The 0% will become the control.
9) Repeat with each solution and each appropriate container. Let them stand for a day.
10) Shake the container to mix any excess solution with vermicompost.
11) Collect 50 young light colored cocoons.
12) Place each set of 10 cocoons in one of the five containers.
13) Store them in an empty worm bin.
14) Check the containers each day to see how many cocoons have hatched.
15) When hatchlings are observed, add a teaspoon of cold cooked oatmeal, made with water.
16) Record the number of hatchlings.
17) Complete Data Table 1.
18) Draw conclusions from the results.

Procedure Optional

1) Press the APPS button; select Datamate.
2) Set up the salinity sensor.

3) Check the salinity of the different solutions. Record the data in the journal and Optional Data Table 1.
4) Repeat Step 3 with a salt water aquarium test kit.

Expectations

The students should be able to:

1) design a reasonable experiment.
2) design the set up.
3) set up the experiment and collect the appropriate data.
4) record the measurements and complete Data Table 1.
5) understand the connection between tolerance and weight loss.

Data Table 1 **Mortality of hatchlings and cocoons**

NaCl (%)	Initial # of cocoons	Final # of cocoons	Loss of cocoons	# of hatchlings observed	Final # of hatchlings	# of surviving hatchlings
0	10					
2	10					
4	10					
8	10					
16	10					

Optional Data Table **Comparison of the solutions' % concentration**

% concentration	Prepared %	Salinity Sensor	+/- difference
0			
2			
4			
8			
16			

Activity 26

Tolerance to Overcrowding

Rationale: At what point in time is the vermiculture too densely populated? Most critters have a tolerance for some overcrowding usually determined by the lack of food and/or abundance of waste.

Objectives

1) Design a study to determine if *E. fetida*/*E. andreii* have a maximum population density.
2) Design the experimental setup
3) Set up experiments, collect data, and analyze the data.

PDE Standards:

Science and Technology
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
Environment and Ecology
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
Math
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

½ -L mini bins (used in previous tolerance activities)
Fresh bedding

Introduction

The problem of overcrowding is apparent in most ecological systems. The carrying capacity of a niche is determined in large part by the number of predators and food supply. The worms in the vermiculture have no predators affecting the study. The food supply is adequate and the waste, castings, could be removed. To determine if there is a behavioral tolerance to overcrowding, this activity will compare the number of cocoons produced with the number of hatchlings produced from cocoons. For commercial growers, the time to harvest worms and castings is more word of mouth and past experience. This may work, but a scientific study could confirm these assumptions.

Strategies

This activity needs to be started as soon as a sufficient number of mature worms are available. This is another low coaching inquiry activity on tolerance. The students need to arrive at a specific number of worms per mini bin or Habitat and the idea that successful reproduction could be used to measure the tolerance. This can be a group per population study or preferably, several groups with 4 sample populations. In the analysis, the number of cocoons and hatchlings produced by the least crowded Habitat will be used as the control number. All other numbers will be compared to that value in Data Table 2.

Procedure

1) Place freshly shredded paper (bedding) in the mini bins.
2) Mix with worms and cocoon-**free** aged vermicompost or peat (50%) potting soil.
3) The new bedding should be half aged and half fresh.
4) Add water equal to three times the mass of the new bedding only. Mix thoroughly.
5) Add about ¾ liter in volume to each mini bin.
6) Collect 60 mature worms.
7) Place 4 in one container, 8 in another, 16 in another, and 32 in another container.
8) Add the appropriate amount of foodstuff to each container for the number of mature worms. Keep sufficient foodstuffs available, but do not overfeed.
9) Once a week look for cocoons, collect the cocoons, and place them on damp filter paper in a plastic Petri dish. Place them in safe darkened room temperature locations. Shoe boxes work well.
10) Be sure the filter paper remains damp.
11) Record the number of cocoons collected from each mini habitat.
12) Record the data in the journal and in Data Table 1.
13) Place all hatchlings in the Habitat or in a new Habitat.
14) Complete Data Table 1 and Data Table 2.
15) Draw conclusions from the results.

Expectations

The students should be able to:

1) design an experiment for tolerance to overcrowding.
2) design an experimental set up.
3) collect appropriate data.
4) record and analyze data.

Data Table 1 Group______

# of worms	cocoons	hatchlings	Cocoons per worm	Hatchlings per worm
4				
8				
16				
32				

Data Table 2

# of Worms	Average # of Cocoons Per Worm	(-) Ave # of cocoons for 4 worms	Difference In Averages	Average # of Hatchlings Per worm	(-) Ave # of hatchlings for 4 worms	Difference in Averages
4		XXXX	XXXX		XXXX	XXXX
8						
16						
32						

Activity 27

Mating Size

Rationale: Do worms select a particular size mate? This activity will attempt to determine the answer to this question. The activity is adapted from "Size-Assortive Mating in the Earthworm, *Eisenia fetida*", Japan Ethnological Society, Springer Verlag, October 6th 2004, (on-line), Fernando Monroy, Manuel Aria, Alberto Veland, and Jorge Dominguez.

Objectives

1) Design an experiment to determine if mate selection is random.
2) Design the experimental set up.
3) Construct the Data Table.
4) Design the method of analysis.

PDE Standards

Science and Technology
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
Environment and Ecology
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
Math
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

50 sexually mature worms from the Habitat
2-L container or larger
Balance
Rulers
Clear plastic soda straws
TI 83/84
Graphical Analysis
Computer

Introduction

This is a very good inquiry approach activity with moderate coaching. Do potential mates, before they mate, make a selection based on similar size or is the mating random? When two sexually mature worms meet, the head end (with mouth and light sensors) touch each other for some time before mating occurs, if it occurs. Is this sensory session merely a greeting or is it a means to establish the size difference?

Strategies

The idea is to catch naturally mating pairs in the habitat and measure their weight and length. Record these measurements as well as the differences. To establish the mass and length of randomly paired worms, the students will collect 50 mature worms and randomly select two worms and take measurements. The mass and length of each are recorded, as well as the difference. This is done until all 25 pairs are measured. In the analysis of the data, the average difference can be noted and discussed. However, the data can be a difference value with pair data entered into List 1 and List 2. The students can complete a 1-Var Stat and look at the average, variance, and standard deviation.

Procedure

1) Select 25 pairs of mating worms. This may take several weeks and requires patience.
2) Record the length and mass of each.
3) Collect 50 mature worms.
4) Select 25 pairs, one pair at a time. Measure the length and weight.
5) Record all measurements in the journal and Data Table 1.
6) Complete Data Table 1.
7) Draw conclusions from the results.

Expectations

The students should be able to:

1) design an experiment to determine if mating size is random.
2) design and set up the experimental equipment.
3) determine and collect appropriate measurements.
4) complete Data Table 1.
5) complete an analysis of the data.

Data Table 1 *(Typical Student Data Table)* **Random Pairs**

Pair #	Mass of A	Mass of B	Δ Mass	Length of A	Length of B	Δ Length
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
Averages	XXXX	XXXX		XXXX	XXXX	

Data Table 1 *(Typical Student Data Table)* **Mating Pairs**

Pair #	Mass of A	Mass of B	Δ Mass	Length of A	Length of B	Δ Length
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
Averages	XXXX	XXXX		XXXX	XXXX	

Activity 28

Growth with Egg Shells

Rationale: Many vermiculturists feel that egg shells or fine sand should be part of the diet. Vermiculture worms have a gizzard and small grains of sand or egg shells will remain in the gizzard to help scour/grind food stuffs for digestion. The egg shells (mostly $CaCO_3$) help to sweeten the vermicompost, as well.

Objectives

1) Design an experimental design for new variables.
2) Design the setup.
3) Analyze the data collected.

PDE Standards

<u>Science and Technology</u>
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
<u>Environment and Ecology</u>
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
<u>Math</u>
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

Crushed dry egg shell
Shredded newsprint
Fine sand
Large mini habitats
Distilled water
TI 83/84

Introduction

The whole concept of the function of a gizzard will be foreign to most students. Chickens and turkeys have gizzards and they are regularly fed a diet with granular limestone. If the vermicompost is only newsprint and water, the diet will not have any grit in it. Therefore, a simple agriculture experiment is apparent – two samples get grits and the other sample does not.

Strategies

This should be as much of an inquiry based experiment as can be accomplished. The experimental design should be very similar to many previous activities. Refrain from over coaching in this activity. It will be necessary to explain how the gizzard functions in the worm's digestive processes. The students should decide to study the effect of grit on the general health of the vermiculture. If the present diet for the worms is void of egg shells, then the students only need to set up two Habitats. The present Habitat will serve as the Habitat without the grit. If the present diet contains egg shells, three new Habitats will be needed.

Procedure

1) Set up 3, 2-liter or larger habitats.
2) Place shredded newsprint in one mini habitat.
3) Mix thoroughly shredded newsprint and an equal mass of finely crushed and dried egg shells.
4) Mix thoroughly shredded newsprint and an equal mass of fine sand.
5) Add water equal to 3 times the mass of the dry newsprint.
6) Add 10 juvenile worms to each mini Habitat.
7) Place in a dark safe environment.
8) Feed immediately and monitor.
9) Record observations in the journal.
10) Remove worms on a regular basis, weigh, and measure the length.
11) Record measurements in the journal and in Data Table 1, 2 or 3.
12) Note the first appearance of cocoons; count and record the numbers.
13) Note the first appearance of hatchlings; count and record the numbers.
14) Complete Data Table 1, 2 or 3.
15) Draw conclusions from the results.

Expectations

The students should be able to:

1) complete a well conceived and designed experiment.
2) a well conceived Data Table.
3) analyze the collected data.

Data Table 1 *(Typical Student Data Table)* **No Grit**

Date	Cocoons		Hatchlings		Increase in Cocoons		Increase In Hatchlings	
	#	Mass	#	Mass	#	Mass	#	Mass
Totals					XXXX		XXXX	
Average Per worm					XXXX		XXXX	

Data Table 2 *(Typical Student Data Table)* **Egg Shell Grit**

Date	**Cocoons**		**Hatchlings**		**Increase in Cocoons**		**Increase In Hatchlings**	
	#	**Mass**	**#**	**Mass**	**#**	**Mass**	**#**	**Mass**
Totals					**XXXX**		**XXXX**	
Average Per worm					**XXXX**		**XXXX**	

Data Table 3 *(Typical Student Data Table)* **Sand Grit**

Date	Cocoons		Hatchlings		Increase in Cocoons		Increase In Hatchlings	
	#	Mass	#	Mass	#	Mass	#	Mass
Totals					**XXXX**		**XXXX**	
Average Per worm					**XXXX**		**XXXX**	

Activity 29

Leaf Litter vs. Shredded Newsprint

Rationale: In nature leaf litter is a by-product of plant metabolism and can present disposal challenges. If leaves can be ground up into small bits can they be used in the Habitat instead of shredded newsprint? Additionally, will the leaves provide extra nutrients not available in newsprint alone?

Objectives

1) Design an experimental design for new variables.
2) Design the setup.
3) Analyze the data collected.

PDE Standards

Science and Technology
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
Environment and Ecology
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
Math
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

2-L bottle (2 per group)
Leaf litter
Distilled water

Introduction

Both newsprint and leaves are by-products of our habitat and must be disposed of to maintain an orderly environment. Certainly, vermiculture does not recycle a significant amount of newsprint, but none-the-less, some is recycled. If leaves can be recycled instead of newsprint, which is recycled at present, that would be a good investment. Leaves contain a lot of possible critters that are not wanted in a healthy vermiculture. On the other hand, worms do not digest all of the foodstuffs by themselves. They get considerable help from a zoo of other very small critters. Because many of these critters found in nature may be absent from the typical indoor vermicompost, leaves may be very beneficial.

Strategies

This should be as much of an inquiry based experiment as can be accomplished. The experimental design should be very similar to many previous activities. Refrain from over coaching in this activity. Students may need to review what chemical and biological active substances remain in the fallen (dead) leaves. The fallen leaves attract many forms of molds, fungi, and protozoa that may or may not be beneficial to the growth and health of the vermiculture. These last few Activities are intended to challenge the students' abilities to design rigorous and well conceived experiments. Provide as little coaching as possible without sacrificing good scholarship.

Procedure

1) Set up 2, 2-liter or larger habitats per group.
2) Place shredded newsprint in one mini habitat.
3) Add water equal to 3 times the mass of the dry newsprint.
4) Dry the leaves thoroughly, crush or grind up.
5) Add water equal to 3 times the mass of the leaves.
6) Add 10 juvenile worms to each mini Habitat.
7) Place in a dark safe environment.
8) Feed immediately and monitor.
9) Record observations in the journal.
10) Remove worms on a regular basis, weigh, and measure their length.
11) Record measurements in the journal and in Data Table 1 or 2.
12) Note the first appearance of cocoons; count and record the numbers.
13) Note the first appearance of hatchlings; count and record the numbers.
14) Complete Data Table 1 or 2.
15) Draw conclusions from the results.

Expectations

The students should be able to:

1) complete a well conceived and designed experiment.
2) a well conceived Data Table.
3) analyze the collected data.

Data Table 1 *(Typical Student Data Table)* **Newsprint**

Date	Cocoons		Hatchlings		Increase in Cocoons		Increase In Hatchlings	
	#	Mass	#	Mass	#	Mass	#	Mass
Totals					**XXXX**		**XXXX**	
Average Per worm					**XXXX**		**XXXX**	

Data Table 2 *(Typical Student Data Table)* **Leaf Litter**

Date	Cocoons		Hatchlings		Increase in Cocoons		Increase In Hatchlings	
	#	Mass	#	Mass	#	Mass	#	Mass
Totals					**XXXX**		**XXXX**	
Average Per worm					**XXXX**		**XXXX**	

Activity 30

Sterile Leaf Litter vs. Natural Leaf Litter

Rationale: To determine whether the microbial life attached to leaves is an important part of the digestive processes for the worms a study must be undertaken. The leaves must be free of microbial life (sterile) that may help in digestion and compared to leaves that are not sterile.

Objectives

1) Design an experimental design for new variables.
2) Design the setup.
3) Analyze the data collected.

PDE Standards

Science and Technology
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
Environment and Ecology
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
Math
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.10.8. A,B
2.11.8. A,B

Materials

2-liter bottles per group
Leaf litter
Sterilized leaf litter.
Oven

Introduction

The introduction of microbial life to the gut of worms is an important aspect of life in the wild. However, these critters may be absent from vermiculture worms, unless the commercial worms carried them to the habitat. It would possible to prevent this from happening by only using cocoons. The cocoons' hatchlings placed in shredded newsprint should be free of the normal microbial culture. Then if cocoons are placed in sterile leaf litter, students may be able to obtain more rigorous results. However, the teacher must decide if the time spent is worth the results.

Strategies

This should be as much of an inquiry based experiment as can be accomplished. The experimental design should be very similar to many previous activities. Refrain from over coaching in this activity. Students may need to review what chemical and biological active substances remain in fallen (dead) leaves. Fallen leaves attract many forms of molds, fungi, and protozoa that may or may not be beneficial to the growth and health of the vermiculture. These last few Activities are supposed to challenge the students' abilities to design rigorous and well conceived experiments. Use as little coaching as possible without sacrificing good scholarship.

Procedure

1) Set up 2, 2-liter or larger habitats per group.
2) Place shredded newsprint in one mini habitat.
3) Add water equal to 3 times the mass of the dry newsprint.
4) Dry the leaves thoroughly, crush or grind up.
5) Add water equal to 3 times the mass of the leaves.
6) Add 10 juvenile worms to each mini Habitat.
7) Place in a dark safe environment.
8) Feed immediately and monitor.
9) Record observations in the journal.
10) Remove worms on a regular basis, weigh, and measure their length.
11) Record measurements in the journal and in Data Table 1 or 2.
12) Note the first appearance of cocoons; count and record the numbers.
13) Note the first appearance of hatchlings; count and record the numbers.
14) Complete Data Table 1 or 2.
15) Draw conclusions from the results.

Expectations

The students should be able to:

1) complete a well conceived and designed experiment.
2) a well conceived Data Table.
3) analyze the collected data.

Data Table 1 *(Typical Student Data Table)* **Sterile Leaf Litter**

Date	Cocoons		Hatchlings		Increase in Cocoons		Increase in Hatchlings	
	#	Mass	#	Mass	#	Mass	#	Mass
Totals					**XXXX**		**XXXX**	
Average Per Worm					**XXXX**		**XXXX**	

Data Table 2 *(Typical Student Data Table)* **Natural Leaf litter**

Date	Cocoons		Hatchlings		Increase in Cocoons		Increase in Hatchlings	
	#	Mass	#	Mass	#	Mass	#	Mass
Totals					**XXXX**		**XXXX**	
Average Per worm					**XXXX**		**XXXX**	

Activity 31

Fast Plants® and Castings

Rationale: The castings and leachate may have some nutrient value for plants. The fast growing plants patented by the University of Wisconsin can be used to quickly determine if these vermiculture products have an effect on the growth of Fast Plants®.

Objectives

1) Learn about Fast Plants®.
2) Design an experiment for determination of the effects of vermiculture products on plant growth.
3) Design an experimental setup.
4) Determine the plant characteristics that indicate better growth.

PDE Standards

<u>Science and Technology</u>
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
<u>Environment and Ecology</u>
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
<u>Math</u>
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

Castings
2-L soda bottles (12)
Balance
Peat moss and vermiculite
Rulers
Fast Plants® seeds

Introduction

Fast Plants® have a very fast growing cycle; they will usually bloom in 14 days. The literature on the Web or included with the plants when purchased will have students using one of several fertilizers such as Osmocote or Peter's Liquid. Students should follow the planting instructions and also use castings. The characteristics of the plants grown in the suggested fertilizer compared to plants fertilized with castings will be the basis of this experiment. Characteristics such as the height of the plant, number of leaves, the area of the leaves, and number of seeds can be used to quantitatively judge the two fertilizers. The plants produce seeds very quickly and these seeds can be used for future experiments, making the purchase of the plants a one-time expenditure.

Strategies

The students need to learn about the methodology for growing Fast Plants® according to the instructions included with the fast plants. The plants that need to be ordered are the normal plants designed for beginning growers. Students will need to make the bottles for growing the plants, as well as the plant mix according to the included instructions. The plant system will need light from fluorescent lights. To help the students complete this Activity, a lot of coaching will be needed. If students are comfortable with growing Fast Plants®, less coaching will be needed to help in the discovery that the castings can be used in one sample and the recommended fertilizer in the other. Osmocote tablets are best for use, since it is a one time process.

Procedure

1) Set up 2 bottles per group as per the directions, using the two soda bottles with a wick. Use 1 part peat moss and 1 part vermiculite for both soil mixtures.
2) Place the appropriate number of Osmocote tablets into one amount of the soil mixture.
3) Place the same mass of dried castings in the other.
4) The seeds need to be started in the film cans according to the directions.
5) Transfer to the bottles according to the directions.
6) Keep an accurate and complete daily record of the growth of the plants in the journal.
7) Record the appropriate measurements in the journal and Data Table 1.
8) Draw conclusions from the results.

Expectations

The students should be able to:

1) correctly set up the plant bottle system.
2) make the soil mixture.
3) add an appropriate amount of castings and Osmocotes tablets.
4) record appropriate measurements.

Data Table 1

Days	Height		# of leaves		# of flowers		# of seeds	
	Osmo	Cast	Osmo	Cast	Osmo	Cast	Osmo	Cast
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								
37								
38								
39								
40								
41								

42				
43				
44				
45				
46				
47				
48				
49				
50				

Activity 32

Growth of Fast Plants® With Castings

Rationale: This Activity will be based on various masses of castings. The optimal mass can be determined by growing plants with differing masses of castings used as fertilizer.

Objectives

1) Determine the optimal mass ratio of castings to soil mixture.
2) Determine the appropriate ratios of castings to soil mixture.
3) Record appropriate measurements.

PDE Standards

Science and Technology
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
Environment and Ecology
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
Math
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.10.8. A,B
2.11.8. A,B

Materials

Fast Plants®seeds
Castings
2-L bottles (20)
Distilled water
Balance
Spatula

Introduction

Fast Plants® grow best under the conditions suggested by the Fast Plants® directions; that is, a specific amount of Osmocote tablets for a specific amount of soil mix. The number of tablets is usually six per bottle-pot. However, there are no data to suggest the amount of castings for the same amount of soil. The Osmocote tablets are placed in the middle of the soil mixture; the castings are mixed thoroughly in the top half of the soil mixture.

Strategies

The amount of coaching for this activity is less than Activity 30, but more than the other inquiry activities. Student discussion should focus on the method to divide the amount of castings in each of the 7 bottle pots. Coaching should help students to decide that the first bottle pot should be below the mass of 6 Osmocotes tablets; the recommended mass for the recommended amount of soil in these pots. The maximum amount should be about 20 times the first amount. Osmocotes tablets are designed to release the fertilizer with changes in temperature over the plant's total life cycle.

Procedure

1) Set up 10 Fast Plants® bottle pots.
2) Set up a bottle pot with zero castings.
3) Measure out one Osmocote tablet's mass of dried castings.
4) Mix the dried castings in the top half of the soil in the first bottle pot.
5) Measure out twice the amount of castings used in the first bottle pot.
6) Mix the castings in the top half of the soil mixture of the second bottle pot.
7) Repeat with the following amounts for the remaining 8 bottle pots.
    a. Bottle 3 = the mass of 4 tablets
    b. Bottle 4 = the mass of 8 tablets
    c. Bottle 5 = the mass of 12 tablets
    d. Bottle 6 = the mass of 16 tablets
    e. Bottle 7 = the mass of 20 tablets
8) Record the measurements in the journal and Data Table 1, 2, 3, 4
9) Complete the Data Tables.
10) Draw conclusions from the results.

Data Table 1 Plant Height vs. Mass of Castings

Day	0	2	4	6	8	12	16	20
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								
37								
38								
39								
40								
41								
42								

43								
44								
45								
46								
47								
48								
49								
50								

Data Table 2 Number of Leaves vs. Mass of Castings

Day	0	2	4	6	8	12	16	20
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								
33								
34								

35								
36								
37								
38								
39								
40								
41								
42								
43								
44								
45								
46								
47								
48								
49								
50								

Data Table 3 Number of Flowers vs. Mass of Castings

Day	1	2	4	6	8	12	16	20
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								

27								
28								
29								
30								
31								
32								
33								
34								
35								
36								
37								
38								
39								
40								
41								
42								
43								
44								
45								
46								
47								
48								
49								
50								

Data Table 4 Number of seeds vs. Mass of Castings

Day	1	2	4	6	8	12	16	20
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								

19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								
37								
38								
39								
40								
41								
42								
43								
44								
45								
46								
47								
48								
49								
50								

Activity 33

Plant Growth with Leachate or Tea

Rationale: This Activity will be based on various masses of castings. The optimal mass can be determined by growing plants with different masses of castings used as fertilizer.

Objectives

1) Determine the optimal percent ratio of leachate to soil mixture.
2) Determine appropriate percent ratios.
3) Record the appropriate measurements.

PDE Standards

<u>Science and Technology</u>
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
<u>Environment and Ecology</u>
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
<u>Math</u>
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A.B.D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

Fast Plants® seeds
Leachate
2-L bottles (20)
Created leachate
Distilled water
50-mL graduated cylinders (10)
100-mL graduated cylinders (10)

Introduction

Fast Plants® grow best under the conditions suggested by the Fast Plants® directions. The bottle pots need to be set up with a wick from the bottom bottle containing water into the soil mix. Specific amounts of leachate will be added to enough distilled water to make a liter of solution to be used to water the plants

Strategies

The amount of coaching for this activity is less than Activity 30, but more than the other inquiry activities. The students' discussions should focus on the method to divide the amount of leachate into each of the 10 bottle pots. The maximum amount should be about 10 times the first amount.

Procedure

1) Set up 10 Fast Plants® bottle pots.
2) Obtain several liters of leachate.
3) Add one part leachate to 9 parts distilled water to make 0.5 L.
4) Pour enough into the soil mixture to arrive at the proper dampness; pour the remainder into the bottom bottle.
5) Add two parts leachate to 8 parts distilled water.
6) Pour enough into the soil mixture to arrive at the proper dampness; pour the remainder into the bottom bottle.
7) Repeat with the following amounts for the remaining 8 bottle-pots.
    a. Bottle 3 - 3 parts leachate to 7 parts distilled water
    b. Bottle 4 - 4 parts leachate to 6 parts distilled water
    c. Bottle 5 - 5 parts leachate to 5 parts distilled water
    d. Bottle 6 - 6 parts leachate to 4 parts distilled water
    e. Bottle 7 - 7 parts leachate to 3 parts distilled water
    f. Bottle 8 - 8 parts leachate to 2 parts distilled water
    g. Bottle 9 - 9 parts leachate to 1 parts distilled water
    h. Bottle 10 - 10 parts leachate to 0 parts distilled water
8) Record the measurements in the journal and Data Table 1, 2, 3, and 4.
9) Complete the Data Tables.
10) Draw conclusions from the results.

Data Table 1 **Plant Height vs. % of Leachate**

Day	1	2	4	6	8	10	14	16	18	20
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										
33										
34										
35										
36										
37										
38										
39										
40										
41										
42										
43										

44										
45										
46										
47										
48										
49										
50										

Data Table 2 Number of Leaves vs. % of Leachate

Day	1	2	4	6	8	10	14	16	18	20
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										
33										
34										
35										

36										
37										
38										
39										
40										
41										
42										
43										
44										
45										
46										
47										
48										
49										
50										

Data Table 3 **Number of Flowers vs. % of Leachate**

Day	**1**	**2**	**4**	**6**	**8**	**10**	**14**	**16**	**18**	**20**
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										

28										
29										
30										
31										
32										
33										
34										
35										
36										
37										
38										
39										
40										
41										
42										
43										
44										
45										
46										
47										
48										
49										
50										

Data Table 4 **Number of seeds vs. % of Leachate**

Day	1	2	4	6	8	10	14	16	18	20
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										

20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										
33										
34										
35										
36										
37										
38										
39										
40										
41										
42										
43										
44										
45										
46										
47										
48										
49										
50										

Activity 34

Plant Growth with Aqueous Castings

Rationale: This activity will be based on various masses of castings. The optimal mass can be determined by growing plants with differing masses of castings used as fertilizer.

Objectives

1) Determine the optimal mass ratio of castings to soil mixture.
2) Determine the appropriate ratios of castings to soil mixture.
3) Record the appropriate measurements.

PDE Standards

Science and Technology
3.1.7. A,B,C
3.2.7. A,B,C,D,E,F
3.6.7. A,B
3.7.7. A,B,C,D
Environment and Ecology
4.1.7. A,B,C
4.2.7. A,C
4.6.7. A,B,C
Math
2.1.8. A,B,D,G
2.2.8. A,B,F
2.3.8. A,B,D
2.4.8. A,B,D,F
2.5.8. A,B,C,D
2.6.8. A,B,C,E,F
2.7.8. B,C,D
2.8.8. F,G,H,I,J
2.11.8. A,B

Materials

Fast Plants® seeds
Castings
2-L bottles (20)
Distilled water
50-mL graduated cylinders (10)
100-mL graduated cylinders (10)

Introduction

Fast Plants® grow best under the conditions suggested by the Fast Plants® directions. The bottle pots need to be set up as designed with a wick from the bottom bottle containing water into the soil mix. Specific amounts of aqueous castings will be added to enough distilled water to make a liter of solution to be used to water the plants. If the Habitat is not producing enough castings, they are for sale on the Internet at very reasonable prices. Keep the castings moist since dry castings are sometimes very difficult to remoisten.

Strategies

The amount of coaching for this activity is less than Activity 30, but more than the other inquiry activities. The students' discussions should focus on the method to divide the amount of aqueous castings into each of the 10 bottle pots. The maximum amount should be about 10 times the first amount.

Procedure

1) Set up 10 Fast Plants® bottle pots.
2) Add 10 g of moist castings to 1 L of distilled water. Mix thoroughly.
3) Pour enough into the soil mixture to arrive at the proper dampness; pour the remainder into the bottom bottle.
4) Add 20 g of moist castings to 1 L of distilled water.
5) Pour enough into the soil mixture to arrive at the proper dampness; pour the remainder into the bottom bottle.
6) Repeat with the following amounts for the remaining 8 bottle-pots.
   a. Bottle 3 - 30 g of castings to 1 liter of distilled water.
   b. Bottle 4 - 40 g of castings to 1 liter of distilled water.
   c. Bottle 5 - 50 g of castings to 1 liter of distilled water.
   d. Bottle 6 - 60 g of castings to 1 liter of distilled water.
   e. Bottle 7 - 70 g of castings to 1 liter of distilled water.
   f. Bottle 8 - 80 g of castings to 1 liter of distilled water.
   g. Bottle 9 - 90 g of castings to 1 liter of distilled water.
   h. Bottle 10 - 100 g of castings to 1 liter of distilled water.
7) Record the measurements in the journal and Data Table 1, 2, 3, and 4.
8) Complete the Data Tables.
9) Draw conclusions from the results.

Data Table 1 **Plant Height vs. % of Aqueous Castings**

Day	1	2	4	6	8	10	14	16	18	20
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										

18										
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										
33										
34										
35										
36										
37										
38										
39										
40										
41										
42										
43										
44										
45										
46										
47										
48										
49										
50										

Data Table 2 **Number of Leaves vs. % of Aqueous Castings**

Day	1	2	4	6	8	10	14	16	18	20
1										
2										
3										
4										
5										
6										
7										
8										
9										

10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										
33										
34										
35										
36										
37										
38										
39										
40										
41										
42										
43										
44										
45										
46										
47										
48										
49										
50										

Data Table 3 Number of Flowers vs. % of Aqueous Castings

Day	1	2	4	6	8	10	14	16	18	20
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										
33										
34										
35										
36										
37										
38										
39										
40										
41										
42										
43										

44										
45										
46										
47										
48										
49										
50										

Data Table 4 **Number of seeds vs. % of Aqueous Castings**

Day	**1**	**2**	**4**	**6**	**8**	**10**	**14**	**16**	**18**	**20**
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										
33										
34										
35										

36										
37										
38										
39										
40										
41										
42										
43										
44										
45										
46										
47										
48										
49										
50										

Activity #35

Coir Vs Shredded Newsprint

Rationale: In the food industry, coir (coconut husks) is a by-product of coconut farming and can present disposal challenges. If coconut husks can be ground up into small bits, can they be used instead of shredded newsprint? Additionally, will the coir provide extra nutrients not available in newsprint alone?

Objectives:

4) To design an experimental design for new variables.
5) To design the set – up.
6) To analyze the data collected

PDE Standards:

Science and Technology

3.1.7.A,B,C
3.2.7.A,B,C,D,E,F
3.6.7.A,B
3.7.7.A,B,C,D

Environment and Ecology

4.1.7.A,B,C
4.2.7.A,C
4.6.7.A,B,C

Math

2.1.8.A,B,D,G
2.2.8.A,B,F
2.3.8.A,B,D
2.4.8.A.B.D,F
2.5.8.A,B,C,D
2.6.8.A,B,C,E,F
2.7.8.B,CD
2.8.8.F.G.H.I.J
2.11.8.A,B

Materials:

2 - Liter bottles (2 per group)
Coir
Distilled water
Newsprint

Introduction:

Both newsprint and coconut husks are by products and must be disposed of to maintain an orderly environment. Certainly, vermiculture does not recycle a significant amount of newsprint, but non-the-less some is recycled. If coir can be recycled as well as newsprint, which is recycled at present, that would be a good investment.

Strategies:

This should be as much of an inquiry based experiment as can be accomplished. The experimental design should be very similar to many previous activities. Refrain from over coaching in this Activity. Students may need to review/search what coir is and how it is manufactured. These last few Activities are supposed to challenge the students' abilities to design rigorous and well conceived experiments. Use as little coaching as possible without sacrificing good scholarship.

Procedure:

16) Set up (2) 2- liter or larger habitats per group.
17) Place shredded newsprint in one mini habitat.
18) Add water equal to 3 times the mass of the dry newsprint.
19) Dry the coir thoroughly, crush or grind up.
20) Add water equal to 3 times the mass of the coir.
21) Add 10 juvenile worms to each mini Habitat.
22) Place in dark safe environment.
23) Feed immediately and monitor.
24) Record observations in your Journal.
25) Remove worms on a regular basis, weigh and measure length.
26) Record measurements in your Journal and in Data Table 1 or 2
27) Note the first appearance of cocoons, count and record numbers.
28) Note the first appearance of hatchlings, count and record numbers.
29) Complete Data Table 1 and 2
30) Draw conclusions from results

Expectations:

The students should be able to:

4) complete a well conceived and designed experiment.
5) a well conceived Data Table.
6) analyze the collected data.

Data Table 1 *(Typical Student Data Table)* **Newsprint**

Date	Cocoons		Hatchlings		Increase Cocoons		Increase In Hatchlings	
	#	Mass	#	Mass	#	Mass	#	Mass
Totals					**XXXX**		**XXXX**	
Average Per worm					**XXXX**		**XXXX**	

Data Table 2 *(Typical Student Data Table)* **Coir**

Date	Cocoons		Hatchlings		Increase Cocoons		Increase In Hatchlings	
	#	Mass	#	Mass	#	Mass	#	Mass
Totals					**XXXX**		**XXXX**	
Average Per worm					**XXXX**		**XXXX**	

Appendix A
Pennsylvania Academic Standards for Science and Technology
Grade 7

3.1.7

A. Explain the parts of a simple system and their relationship to each other.
1. Describe a system as a group of related parts that work together to achieve a desired result (e.g., digestive system).
2. Explain the importance of order in a system.
3. Distinguish between system inputs, system processes, and system outputs.
4. Distinguish between open loop and closed loop systems.
5. Apply systems analysis to solve problems.

B. Describe the use of models as an application of scientific or technological concepts.
1. Identify and describe different types of models and their functions.
2. Apply models to predict specific results and observations (e.g., population growth, effects of infectious organisms).
3. Explain systems by outlining a system's relevant parts and its purpose and/or designing a model that illustrates its function.

C. Identify patterns as repeated processes or recurring elements in science and technology.
1. Identify different forms of patterns and use them to group and classify specific objects.
2. Identify repeating structure patterns.
3. Identify and describe patterns that occur in physical systems (e.g., construction, manufacturing, transportation), informational systems, and biochemically related systems.
4. Explain scale as a way of relating concepts and ideas to one another by some measure.
6. Apply various applications of size and dimensions of scale to scientific, mathematical, and technological applications.
7. Describe scale as a form of ratio and apply to a life situation.
8. Identify change as a variable in describing natural and physical systems.
9. Describe fundamental science and technology concepts that could solve practical problems.
10. Explain how ratio is used to describe change.
11. Describe the effect of making a change in one part of a system on the system as a whole.

3.2.7

A. Explain and apply scientific and technological knowledge.
1. Distinguish between a scientific theory and a belief.
2. Answer "What if" questions based on observation, inference or prior knowledge or experience.

3. Explain how skepticism about an accepted scientific explanation has led to a new understanding.
4. Explain how new information may change existing theories and practice.

B. Apply process knowledge to make and interpret observations.
   1. Measure materials using a variety of scales.
   2. Describe relationships by making inferences and predictions.
   3. Communicate, use space/time relationships, define operationally, raise questions, formulate hypotheses, test, and experiment,
   4. Design controlled experiments, recognize variables, and manipulate variables.
   5. Interpret data, formulate models, design models, and produce solutions.

C. Identify and use the elements of scientific inquiry to solve problems.
   1. Generate questions about objects, organisms and/or events that can be answered through scientific investigations.
   2. Evaluate the appropriateness of questions.
   3. Design an investigation with limited variables to investigate a question.
   4. Conduct a two-part experiment.
   5. Judge the significance of experimental information in answering the question.
   6. Communicate appropriate conclusions from an experiment.
   7. Know and use the technological design process to solve problems.
   8. Define different types of problems.
   9. Define all aspects of the problem, necessary information, and questions that must be answered.
   10. Propose the best solution.
   11. Design and propose alternative methods to achieve solutions.
   12. Apply a solution.
   13. Explain the results, present improvements, identify and infer the impacts of the solution.

3.3.7

A. Describe the similarities and differences that characterize diverse living things.
   1. Describe how the structures of living things help them function in unique ways.
   2. Explain how to use a dichotomous key to identify plants and animals.
   3. Account for adaptations among organisms that live in a particular environment.
   4. Describe the cell as the basic structural and functional unit of living things.
   5. Identify the levels of organization from cell to organism.
   6. Compare life processes at the organism level with life processes at the cell level.
   7. Explain that cells and organisms have particular structures that underlie their functions.
   8. Describe and distinguish among cell cycles, reproductive cycles, and life cycles.

9. Explain disease effects on structures or functions of an organism.

C. Know that every organism has a set of genetic instructions that determines its inherited traits.
   1. Identify and explain inheritable characteristics.
   2. Identify that the gene is the basic unit of inheritance.
   3. Identify basic patterns of inheritance (e.g., dominance, recessive, co-dominance).
   4. Describe how traits are inherited.
   5. Distinguish how different living things reproduce (e.g., vegetative budding, sexual).
   6. Recognize that mutations can alter a gene.
   7. Describe how selective breeding, natural selection, and genetic technologies can change the genetic makeup of organisms.

D. Explain basic concepts of natural selection.
   1. Identify adaptations that allow organisms to survive in their environment.
   2. Describe how an environmental change can affect the survival of organisms and entire species.
   3. Know that differences in individuals of the same species may give some advantage in surviving and reproducing.
   4. Recognize that populations of organisms can increase rapidly.
   5. Describe the role that fossils play in studying the past.
   6. Explain how biologic extinction is a natural process.

3.4.7

A. Describe concepts about the structure and properties of matter.
   1. Identify elements as basic building blocks of matter that cannot be broken down chemically.
   2. Distinguish compounds from mixtures.
   3. Describe and conduct experiments that identify chemical and physical properties.
   4. Describe reactants and products of simple chemical reactions.

B. Relate energy sources and transfers to heat and temperature.
   1. Identify and describe sound changes in moving objects.
   2. Know that the sun is a major source of energy that emits wavelengths of visible light, infrared, and ultraviolet radiation.
   3. Explain the conversion of one form of energy to another by applying knowledge of each form of energy.
   4. Explain the parts and functions in an electrical circuit.

C. Identify and explain the principles of force and motion.
   1. Describe the motion of an object based on its position, direction, and speed.
   2. Classify fluid power systems according to fluid used or mode of power transmission (e.g., air, oil).

3. Explain various motions using models.
4. Explain how convex and concave mirrors and lens change light images.
5. Explain how sound and light travel in waves of differing speeds, sizes and frequencies.

D. Describe essential ideas about the composition and structure of the universe and the earth's place in it.
   1. Compare various planets' characteristics.
   2. Describe basic star types and identify the sun as a star type.
   3. Describe and differentiate comets, asteroids and meteors.
   4. Identify gravity as the force that keeps planets in orbit around the sun and governs the rest of the movement of the solar system and the universe.
   5. Illustrate how the positions of stars and constellations change in relation to the Earth during an evening and from month to month.
   6. Identify equipment and instruments that explore the universe.
   7. Identify the accomplishments and contributions provided by selected past and present scientists in the field of astronomy.
   8. Identify and articulate space program efforts to investigate possibilities of living in space and on other planets.

3.5.7

A. Describe earth features and processes.
   1. Describe major layers of the earth.
   2. Describe the processes involved in the creation of geologic features (e.g., folding, faulting, volcanism, sedimentation) and that these processes seen today (e.g., erosion, weathering, and crustal plate movement) are similar to those in the past.
   3. Describe the processes that formed Pennsylvania geologic structures and resources including mountains, glacial formations, water gaps, and ridges.
   4. Explain how the rock cycle affected rock formations in the state of Pennsylvania.
   5. Distinguish between examples of rapid surface changes (e.g., landslides, earthquakes) and slow surface changes (e.g., weathering).
   6. Identify living plants and animals that are similar to fossil forms.

B. Recognize earth resources and how they affect everyday life.
   1. Identify and locate significant earth resources (e.g., rock types, oil, gas, coal deposits) in Pennsylvania.
   2. Explain the processes involved in the formation of oil and coal in Pennsylvania.
   3. Explain the value and uses of different earth resources (e.g., selected minerals, ores, fuel sources, and agricultural uses).
   4. Compare the locations of human settlements as related to available resources.

C. Describe basic elements of meteorology.

1. Explain weather forecasts by interpreting weather data and symbols.
2. Explain the oceans' impact on local weather and the climate of a region.
3. Identify how cloud types, wind directions, and barometric pressure changes are associated with weather patterns in different regions of the country.
4. Explain and illustrate the processes of cloud formation and precipitation.
5. Describe and illustrate the major layers of the earth's atmosphere.
6. Identify different air masses and global wind patterns and how they relate to the weather patterns in different regions of the U.S.

D. Explain the behavior and impact of the earth's water systems.
1. Explain the water cycle using the processes of evaporation and condensation.
2. Describe factors that affect evaporation and condensation.
3. Distinguish salt from fresh water (e.g., density, electrical conduction).
4. Compare the effect of water type (e.g., polluted, fresh, salt water) and the life contained in them.
5. Identify ocean and shoreline features, (e.g., bays, inlets, spit, tidal marshes).

3.6.7

A. Explain biotechnologies that relate to related technologies of propagating, growing, maintaining, adapting, treating, and converting.
1. Identify the environmental, societal, and economic impacts that waste has in the environment.
2. Identify and explain the impact that a specific medical advancement has had on society.
3. Explain the factors that were taken into consideration when a specific object was designed.
4. Define and describe how fuels and energy can be generated through the process of biomass conversion.
5. Identify and group basic plant and animal production processes.
6. Explain the impact that agricultural science has had on biotechnology.

B. Explain information technologies of encoding, transmitting, receiving, storing, retrieving, and decoding.
1. Demonstrate the effectiveness of an image generating technique to communicate a story (e.g., photography, video).
2. Analyze and evaluate the effectiveness of a graphic object designed and produced to communicate a thought or concept.
3. Apply basic technical drawing techniques to communicate an idea or solution to a problem.
4. Apply the appropriate method of communications technology to communicate a thought.

C. Explain physical technologies of structural design, analysis and engineering, personnel relations, financial affairs, structural production, marketing, research, and design.

1. Use knowledge of material effectiveness to solve specific construction problems (e.g., steel vs. wood bridges).
2. Differentiate among the different types of construction applications (e.g., microwave tower, power plants, and aircrafts).
3. Explain basic material processes that manufactured objects undergo during production. (e.g., separating, forming, and combining).
4. Evaluate a construction activity by specifying task analyses and necessary resources.
5. Explain the relationships among the basic resources needed in the production process for a specific manufactured object.
6. Explain the difference between design engineering and production engineering processes.
7. Analyze manufacturing steps that affect waste and pollutants.
8. Explain transportation technologies of propelling, structuring, suspending, guiding, controlling, and supporting.
9. Identify and explain the workings of several mechanical power systems.
10. Model and explain examples of vehicular propulsion, control, guidance, structure, and suspension systems.
11. Explain the limitations of land, marine, air, and space transportation systems.

3.7.7

A. Describe the safe and appropriate use of tools, materials, and techniques to answer questions and solve problems.
   1. Identify uses of tools, machines, materials, information, people, money, energy, and time that meet specific design criteria.
   2. Describe safe procedures for using tools and materials.
   3. Assess materials for appropriateness of use.

B. Use appropriate instruments and apparatus to study materials.
   1. Select appropriate instruments to measure the size, weight, shape, and temperature of living and non-living objects.
   2. Apply knowledge of different measurement systems to measure and record objects' properties.

C. Explain and demonstrate basic computer operations and concepts.
   1. Know specialized computer applications used in the community.
   2. Describe the function of advanced input and output devices (e.g., scanners, video images, plotters, projectors) and demonstrate their use.
   3. Demonstrate age appropriate keyboarding skills and techniques.

D. Apply computer software to solve specific problems.
   1. Identify software designed to meet specific needs (e.g., Computer Aided Drafting, design software, tutorial, financial, presentation software).
   2. Identify and solve basic software problems relevant to specific software applications.
   3. Identify basic multimedia applications.

4. Demonstrate a basic knowledge of desktop publishing applications.
5. Apply intermediate skills in utilizing word processing, database, and spreadsheet software.
6. Apply basic graphic manipulation techniques.

D. Explain basic computer communications systems.
1. Describe the organization and functions of the basic parts that make up the World Wide Web.
2. Apply advanced electronic mail functions.
3. Apply basic on-line research techniques to solve a specific problem.

3.8.7

A. Explain how sciences and technologies are limited in their effects and influences on society.
1. Identify and describe the unavoidable constraints of technological design.
2. Identify changes in society as a result of a technological development.
3. Identify and explain improvements in transportation, health, sanitation, and communications as a result of advancements in science and technology and how they effect our lives.

B. Explain how human ingenuity and technological resources satisfy specific human needs and improve the quality of life.
1. Identify interrelationships between systems and resources.
2. Identify and describe the resources necessary to solve a selected problem in a community and improve the quality of life.
3. identify and explain specific examples of how agricultural science has met human needs and has improved the quality of life.

C. Identify the pros and cons of applying technological and scientific solutions to address problems and the effect upon society.
1. Describe the positive and negative expected and unexpected effects of specific technological developments.
2. Describe ways technology extends and enhances human abilities.

Appendix B.
Pennsylvania Academic Standards for Environment and Ecology
Grade 7

4.1.7

A. Explain the role of the water cycle within a watershed.
1. Explain the water cycle.
2. Explain the water cycle as it relates to a watershed.

B. Understand the role of the watershed.
1. Identify and explain what determines the boundaries of a watershed.
2. Explain how water enters a watershed.
3. Explain factors that affect water quality and flow through a watershed.

C. Explain the effects of water on the life of organisms in a watershed.
1. Explain how water is necessary for all life.
2. Explain how the physical components of aquatic systems influence the organisms that live there in terms of size, shape and physical adaptations.
3. Describe the life cycle of organisms that depend on water.
4. Identify organisms that have aquatic stages of life and describe those stages.

D. Explain and describe characteristics of a wetland.
1. Identify specific characteristics of wetland plants and soils.
2. Recognize the common types of plants and animals.
3. Describe different types of wetlands.
4. Describe the different functions of a wetland.

E. Describe the impact of watersheds and wetlands on people.
1. Explain the impact of watersheds and wetlands in flood control, wildlife habitats, and pollution abatement.
2. Explain the influence of flooding on wetlands.

4.2.7.

A. Know that raw materials come from natural resources.
1. Identify resources used to provide humans with energy, food, housing and water.
2. Explain how plants and animals may be classified as natural resources.
3. Compare means of growing or acquiring food.
4. Identify fiber and other raw materials used in clothing and shelter production.
5. Identify types of minerals and fossil fuels used by humans.

B. Examine the renewability of resources.
1. Identify renewable resources and describe their uses.
2. Identify nonrenewable resources and describe their uses.
3. Compare finished products to their original raw material.
4. Identify the waste derived from the use of renewable and nonrenewable

resources.
5. Determine how consumption may impact the availability of resources.
6. Compare the time spans of renewability for fossil fuels and alternative fuels.

C. Explain natural resource distribution.
1. Distinguish between readily available and less accessible resources.
2. Identify the locations of different concentrations of fossil fuels and mineral resources.
3. Analyze the effects of management practices on air, land and water in forestry, agriculture, fisheries, wildlife, mining, and food and fiber production that are unique to different climates.

D. Describe the role of recycling and waste management.
1. Identify materials that can be recycled in the community.
2. Explain the process of closing the loop in recycling.
3. Compare the decomposition rates of different organic materials.
4. Describe methods that could be used to reuse materials for new products.
5. Evaluate the costs and benefits of disposable products.

4.3.7

A. Identify environmental health issues.
1. Identify various examples of long-term pollution and explain their effects on environmental health.
2. Identify diseases that have been associated with poor environmental quality.
3. Describe different types of pest controls and their effects on the environment.
4. Identify alternative products that can be used in life to reduce pollution.

B. Describe how human actions affect the health of the environment.
1. Identify land use practices and their relation to environmental health.
2. Explain how natural disasters affect environmental health.
3. Identify residential and industrial sources of pollution and their effects on environmental health.
4. Explain the difference between point and nonpoint source pollution.
5. Explain how nonpoint source pollution can affect the water supply and air quality.
6. Explain how acid deposition can affect water, soil and air quality.
7. Explain the relationship between resource use, reuse, recycling and environmental health.

C. Explain biological diversity.
1. Explain the complex, interactive relationships among members of an ecosystem.
2. Explain how diversity affects ecological integrity of the natural resources.

4.4.7.

A. Explain society's standard of living in relation to agriculture.
   1. Compare and contrast agricultural changes that have been made to meet society's needs.
   2. Compare and contrast how animals and plants affect agricultural systems.
   3. Compare several technological advancements and their effect(s) on the historical growth of agriculture.
   4. Compare different environmental conditions related to agricultural production, cost, and quality of a product.

B. Investigate how agricultural science has recognized the various soil types found in Pennsylvania.
   1. Explain the importance of particle sizes in different soil types.
   2. Determine how water has influenced the development of Pennsylvania soil types.
   3. Investigate how soil types have influenced the plant types used on Pennsylvania farms.
   4. Analyze how soil types and geographic regions have impacted the profitability of Pennsylvania farms.

C. Explain agricultural systems' use of natural and human resources.
   1. Analyze the needs of plants and animals as they relate to climate and soil conditions.
   2. Identify the plants and animals that can be raised in the area and explain why.
   3. Identify natural resources necessary for agricultural systems.
   4. Compare the need for crop production to the need for animal production.
   5. Define issues associated with food and fiber production.

D. Explain the improvement of agricultural production through technology.
   1. Compare the technologies that have advanced agricultural production.
   2. Explain how energy sources have changed to meet agricultural technology.

4.5.7.

A. Explain benefits and harmful effects of pests.
   1. Identify different examples of pests and explain the beneficial or harmful effects of each.
   2. Identify several locations where pests can be found and compare the effects the pests have on each location.

B. Explain how pest management affects the environment.
   1. Explain issues related to integrated pest management including biological technology, resistant varieties, chemical practices, medical technology, and monitoring techniques.
   2. Describe how integrated pest management and related technology impact human activities.
   3. Identify issues related to integrated pest management that affect the

environment.

C. Explain various integrated pest management practices used in society.
   1. Compare and contrast integrated pest management monitoring methods utilized in different community settings.
   2. Compare integrated pest management to past practices.
   3. Compare and analyze the long-term effects of using integrated pest management products.

4.6.7.

A. Explain the flow of energy and matter from organism to organism within an ecosystem.
   1. Identify and explain the characteristics of biotic and abiotic.
   2. Describe and explain the adaptations of plants and animals to their environment.
   3. Demonstrate the dependency of living components in the ecosystem on the nonliving components.
   4. Explain energy flow through a food web.
   5. Explain the importance of the predator/prey relationship and how it maintains the balance within ecosystems.
   6. Understand limiting factors and predict their effects on an organism.
   7. Identify niches for producers, consumers, and decomposers within an ecosystem.
   8. Compare and contrast the major ecosystems of Pennsylvania.
   9. Identify the major characteristics of a biome.
   10. Compare and contrast different biomes and their characteristics.
   11. Identify the relationship of abiotic and biotic components and explain their interaction in an ecosystem.
   12. Explain how different soil types determine the characteristics of ecosystems.

B. Explain the concepts of cycles.
   1. Identify and explain cycles within an ecosystem.
   2. Analyze the role of different cycles within an ecosystem.

C. Explain how ecosystems change over time.
   1. Explain how ecosystems change.
   2. Explain how specific organisms may change an ecosystem.
   3. Explain a change in an ecosystem that relates to humans.

4.7.7.

A. Describe diversity of plants and animals in ecosystems.
   1. Select an ecosystem and describe different plants and animals that live there.
   2. Identify adaptations in plants and animals.
   3. Recognize that adaptations are developed over long periods of time and are passed on from one generation to the next.
   4. Understand levels of ecosystem organization (e.g., individuals, populations,

species).

B. Explain how species of living organisms adapt to their environment.
   1. Explain the role of individual variations in natural selection.
   2. Explain how an adaptation is an inherited structure or behavior that helps an organism survive and reproduce.
   3. Describe how a particular trait may be selected over time and account for a species' adaptation.
   4. Compare and contrast animals and plants that have very specific survival requirements with those that have more general requirements for survival.
   5. Explain how living things respond to changes in their environment.
   6. Explain how one species may survive an environmental change while another might not.

C. Explain natural or human actions in relation to the loss of species.
   1. Identify natural or human impacts that cause habitat loss.
   2. Explain how habitat loss can affect the interaction among species and the population of a species.
   3. Analyze and explain the changes in an animal population over time.
   4. Explain how a habitat management practice affects a population.
   5. Explain the differences among threatened, endangered, and extinct species.
   6. Identify Pennsylvania plants and animals that are on the threatened or endangered list.
   7. Describe state laws passed regarding threatened and endangered species in Pennsylvania.
   8. Explain why one species may be more susceptible to becoming endangered than another species.

4.8.7.

A. Describe how the development of civilization relates to the environment.
   1. Explain how people use natural resources in their environment.
   2. Locate and identify natural resources in different parts of the world.
   3. Compare and contrast how people use natural resources throughout the world.

B. Explain how people use natural resources.
   1. Describe how natural resources are used for survival.
   2. Explain how natural resources and technological changes have affected the development of civilizations.
   3. Explain how climate and extreme weather events (e.g., drought, flood) influence people's lives.

C. Explain how human activities may affect local, regional and national environments.
   1. Describe what effect consumption and related generation of wastes have on the environment.

2. Explain how a particular human activity has changed the local area over the years.

D. Explain the importance of maintaining the natural resources at the local, state and national levels.
   1. Explain how human activities and natural events have affected ecosystems.
   2. Explain how conservation practices have influenced ecosystems.
   3. Define the roles of Pennsylvania agencies that deal with natural resources.

4.9.7.

A. Explain the role of environmental laws and regulations.
   1. Identify and explain environmental laws and regulations (e.g., Clean Air Act, Clean Water Act, Recycling and Waste Reduction Act, Act 26 on Agricultural Education).
   2. Explain the role of local and state agencies in enforcing environmental laws and regulations (e.g., Department of Environmental Protection, Department of Agriculture, Game Commission).

Appendix C
Pennsylvania Academic Standards for Math
Grade 8

2.1.8

A. Represent and use numbers in equivalent forms (e.g., integers, fractions, decimals, percents, exponents, scientific notation, square roots).
B. Simplify numerical expressions involving exponents, scientific notation and using order of operations.
C. Distinguish between and order, rational, and irrational numbers.
D. Apply ratio and proportion to mathematical problem situations involving distance, rate, time and similar triangles.
E. Simplify and expand algebraic expressions using exponential forms.
F. Use the number line model to demonstrate integers and their applications.
G. Use the inverse relationships between addition, subtraction, multiplication, division, exponentiation, and root extraction to determine unknown quantities in equations.

2.2.8

A. Complete calculations by applying the order of operations.
B. Add, subtract, multiply, and divide different kinds and forms of rational numbers including integers, decimal fractions, percents, and proper and improper fractions.
C. Estimate the value of irrational numbers.
D. Estimate amount of tips and discounts using ratios, proportions, and percents.
E. Determine the appropriateness of overestimating or underestimating in computation.
F. Identify the difference between exact value and approximation and determine which is appropriate for a given situation.

2.3.8

A. Develop formulas and procedures for determining measurements (e.g., area, volume, distance).
B. Solve rate problems (e.g., rate × time = distance, principal × interest rate = interest).
C. Measure angles in degrees and determine the relationships of angles.
D. Estimate, use, and describe measures of distance, rate, perimeter, area, volume, weight, mass, and angles.
E. Describe how a change in linear dimension of an object affects its perimeter, area, and volume.
F. Use scale measurements to interpret maps or drawings.
G. Create and use scale models.

2.4.8

A. Make conjectures based on logical reasoning and test conjectures by using counter-examples.
B. Combine numeric relationships to arrive at a conclusion.
C. Use if...then statements to construct simple, valid arguments.
D. Construct, use, and explain algorithmic procedures for computing and estimating with whole numbers, fractions, decimals, and integers.
E. Distinguish between inductive and deductive reasoning.
F. Use measurements and statistics to quantify issues (e.g., in family, consumer science situations).

2.5.8

A. Invent, select, use, and justify the appropriate methods, materials, and strategies to solve problems.
B. Verify and interpret results using precise mathematical language, notation and representations, including numerical tables and equations, simple algebraic equations and formulas, charts, graphs, and diagrams.
C. Justify strategies and defend approaches used and conclusions reached.
D. Determine pertinent information in problem situations and whether any further information is needed for a solution.

2.6.8

A. Compare and contrast different plots of data using values of mean, median, mode, quartiles, and range.
B. Explain effects of sampling procedures and missing or incorrect information on reliability.
C. Fit a line to the scatter plot of two quantities and describe any correlation of the variables.
D. Design and carry out a random sampling procedure.
E. Analyze and display data in stem-and-leaf and box-and-whisker plots.
F. Use scientific and graphing calculators and computer spreadsheets to organize and analyze data.
G. Determine the validity of the sampling method described in studies published in local or national newspapers.

2.7.8

A. Determine the number of combinations and permutations for an event.
B. Present the results of an experiment using visual representations (e.g., tables, charts, graphs).
C. Analyze predictions (e.g., election polls).
D. Compare and contrast results from observations and mathematical models.
E. Make valid inferences, predictions, and arguments based on probability.

2.8.8

A. Apply simple algebraic patterns to basic number theory and to spatial relations.
B. Discover, describe, and generalize patterns, including linear, exponential, and simple quadratic relationships.
C. Create and interpret expressions, equations or inequalities that model problem situations.
D. Use concrete objects to model algebraic concepts.
E. Select and use a strategy to solve an equation or inequality, explain the solution, and check the solution for accuracy.
F. Solve and graph equations and inequalities using scientific and graphing calculators and computer spreadsheets.
G. Represent relationships with tables or graphs in the coordinate plane and verbal or symbolic rules.
H. Graph a linear function from a rule or table.
I. Generate a table or graph from a function and use graphing calculators and computer spreadsheets to graph and analyze functions.
J. Show that an equality relationship between two quantities remains the same as long as the same change is made to both quantities; explain how a change in one quantity determines another quantity in a functional relationship.

2.9.8

A. Construct figures incorporating perpendicular and parallel lines, the perpendicular bisector of a line segment and an angle bisector using computer software.
B. Draw, label, measure, and list the properties of complementary, supplementary, and vertical angles.
C. Classify familiar polygons as regular or irregular up to a decagon.
D. Identify, name, draw, and list all properties of squares, cubes, pyramids, parallelograms, quadrilaterals, trapezoids, polygons, rectangles, rhombi, circles, spheres, triangles, prisms, and cylinders.
E. Construct parallel lines, draw a transversal, and measure and compare angles formed (e.g., alternate interior and exterior angles).
F. Distinguish between similar and congruent polygons.
G. Approximate the value of π (pi) through experimentation.
H. Use simple geometric figures (e.g., triangles, squares) to create, through rotation, transformational figures in three dimensions.
I. Generate transformations using computer software.
J. Analyze geometric patterns (e.g., tessellations, sequences of shapes) and develop descriptions of the patterns.
K. Analyze objects to determine whether they illustrate tessellations, symmetry, congruence, similarity, and scale.

2.10.8

A. Compute measures of sides and angles using proportions, the Pythagorean Theorem, and right triangle relationships.
B. Solve problems requiring indirect measurement for the lengths of sides of triangles.

2.11.8

A. Analyze graphs of related quantities for minimum and maximum values and justify the findings.
B. Describe the concept of unit rate, ratio, and slope in the context of rate of change.
C. Continue a pattern of numbers or objects that could be extended infinitely.