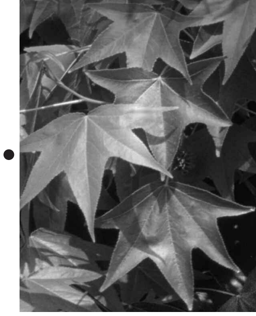
7

COMPOSTING RESEARCH



Vermiculturists assert that worm castings are the most valuable commodity in the garden and that you can take raw pig manure and run it through worms to totally remove the pathogens and add countless new minerals while improving texture. Non-worm composters insist that worms lock up nutrients, destroy microorganisms, and result in a product that is less nutritive… My bottom line is simple, I am trying to determine what has been proven in order to arrive at an approach that integrates the best of what we know—without hype or speculation...

—E-mail message from frustrated compost manager

Welcome to the frontiers of science. I know this can be frustrating, but the debate and contradictions you experience are not likely to be resolved quickly… I recommend you approach the field of composting with skepticism as well as an open mind. An open mind is essential to understand some of the great composting mysteries that are almost certainly out there, perhaps related to the role of microbes or various unconventional practices. But skepticism is also critical, especially when listening to those who are certain they already know all the answers.

Best wishes on your journey!

—Response from compost scientist Tom Richard

Throughout *Composting in the Classroom*, we not only have presented information but also have pointed out gaps in our knowledge. And, even the information we have presented represents only the most current understanding about composting. As new information is added, our understanding of composting processes will be enhanced, and recommendations for composting procedures will change.

Maybe your students are intrigued by one of the research possibilities we have presented. Or, maybe they have questions of their own that could be developed into a research project. Perhaps their past experiences with composting caused them to doubt some of the information that has been presented, and they would like to test the validity of their own observations.

This final chapter is for those students who have posed questions in the course of exploring material in this manual and are eager to conduct research to find answers. Many of the techniques presented in Chapters 3–5, as well as the background information presented in Chapter 1, should be useful in designing and conducting experiments. The discussion of plant growth experiments in Chapter 6 has already provided an introduction to some of the issues encountered in conducting research.

This chapter presents a short overview of research as conducted by scientists, as well as some example research projects. Students can use the example research possibilities presented throughout this publication as models for their research, or they may devise entirely new projects.

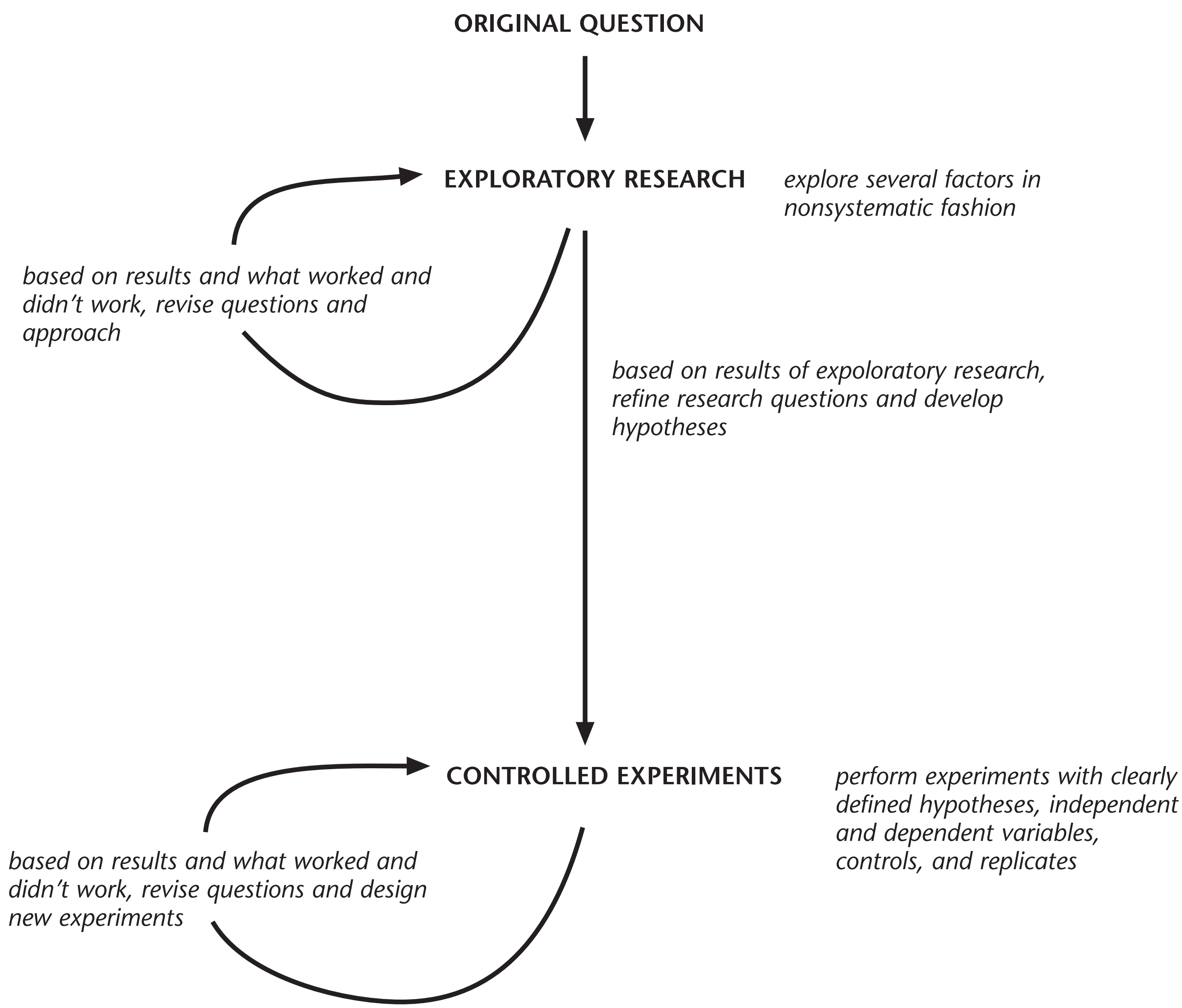
EXPLORATION AND CONTROLLED EXPERIMENTS

Students and scientists working in a new field often start off with *exploratory research* (Figure 7–1). In this type of research, students or scientists are *exploring* or gaining a "feel for" an organism or process by using a variety of methods. An example of exploratory research would be students trying various mixtures of compost ingredients, testing their effects on the peak temperature reached and the length of time the temperature remained elevated. Another example of exploratory research would be students comparing the microbial populations in different composts. Or, students interested in the physical sciences could investigate how different bioreactor designs affect the temperatures achieved during the composting process. Such explorations would lead to a series of observations about the variables that could be changed or investigated in a more controlled manner in order to answer a more defined research question.

Based on results obtained during their exploratory research, students might refine their research questions and plans, leading to design and execution of a controlled scientific experiment. *Controlled experiments*[1] are carefully designed to include clearly defined objectives and hypotheses, dependent and independent variables, one or more treatments or levels of the independent variable, and replicates for each treatment. Based on their exploratory research, students studying compost microbiology might hypothesize that composts with high levels of nitrogen support more microbial activity. The next step would be to design an experiment to test this hypothesis, by purposefully varying the nitrogen content of the compost mix while keeping all other variables constant. Similarly, the students investigating bioreactors might have discovered through their exploratory research that systems smaller than a certain size lose heat too quickly to achieve the optimal temperatures for composting. These students could design a controlled experiment focusing on whether insulation can compensate for the larger surface-to-volume ratio in small compost systems. Or, they might choose to investigate whether the addition of an outside energy source enhances thermophilic composting in small bioreactors. In either case, the students would vary only one independent variable (insulation or outside energy source), keeping the size of the pile, mix of ingredients, ambient temperature, and other factors constant.

It should be noted that not all exploratory research leads to controlled experiments. Some students may not be ready to move on to controlled experiments, and they may be better served by conducting several exploratory projects. Because it is so open-ended and allows students so much freedom in designing their projects, exploratory research can serve to motivate students with differing abilities. Classroom discussions of the results of students' research projects can guide the teacher in determining when to introduce more advanced concepts such as replication and controls, and when to allow students to conduct further exploratory research in a more open-ended manner.

Figure 7–1. Model for Conducting Research.



NARROWING DOWN A RESEARCH QUESTION

One of the most difficult aspects of conducting research is framing a research question that can be answered using the means available. In exploratory research, this is less important, because the goals are for students to become acquainted with a particular process or organism and for them to get excited about research. The results of exploratory research can often be used to identify trends, but they are not expected to yield solid conclusions. In fact, exploratory research is often used to help narrow down a question that can be answered by a controlled experiment.

The goal of controlled experimental research is to answer specific questions. However, the results of a controlled experiment will be difficult to interpret if the original question is not well defined.

For example, suppose that your students wanted to know whether compost enhances the growth of plants. They might start off by bringing in samples of home compost and using it as mulch around their favorite plants in the school yard. Once their results are in, it may be difficult to conclude why some plants grew faster than others. Was it because of differences in the species of the plant, or whether they were growing in the sun or shade? Was plant growth affected by the type of compost applied, or the amount? Although it will be hard to draw conclusions with so many variables, the students may notice a particularly interesting result or trend that stands out. For example, all the plants near the south-facing wall of the building grew particularly well regardless of the compost treatment. Could this be due to higher temperatures in that area of the school yard? You could use the students' observations to help them design a new, controlled experiment on the effect of temperature on plant growth.

Alternatively, you could go back to the original question about the effect of compost on plant growth, and use the results of the experiment to help the students narrow down a better research question. An example of a better-defined research question is, "What is the effect of vermicompost produced from cafeteria wastes on the growth of kidney beans?" Students can further narrow this question to: "What is the effect of adding different amounts of vermicompost to school-yard soil on the growth of kidney beans in pots?" They have now defined a question that can be answered in a controlled experiment, by varying the ratio of vermicompost to soil and growing the kidney beans under the same watering, light, and temperature regime.

EXAMPLE RESEARCH PROJECTS

Some ideas for research projects have been presented throughout this manual. We encourage students to use these and their own ideas to develop explorations and experiments. The following is an example of how the same question might be examined through both exploratory research and controlled experiments.

How long does it take for different composts to become stable?

Exploratory Research: Students could mix together various organic materials and measure the compost respiration rates at several-day intervals after the thermophilic stage has been completed.

Controlled Experimental Research: Students could design an experiment with carefully measured quantities of various ingredients. They would choose only two ingredients and vary their relative amounts. The total volume of wastes, ambient temperature, and moisture content should be kept constant. There would be at least three replicates of each treatment. From each replicate, respiration would be measured at each sampling time. The results would be presented as the mean (and standard error if students are familiar with this measure) of the measurements for each treatment at each sampling time. Any unexpected results should be presented.

The following are two examples of how an exploratory research project can lead into a controlled experiment.

How does the compost/soil mix affect the growth of lettuce seeds?

Exploratory Research: Students could start off by growing lettuce seeds in a variety of compost/soil mixes and measuring various properties of the different mixes (e.g., porosity, water holding capacity, pH). They might observe that lettuce seeds grow best within a narrow range of pH, regardless of the porosity or water holding capacity.

Controlled Experimental Research: Students could define a new question based on the results of their exploratory research. What is the effect of the pH of a compost/soil mix on the growth of lettuce seeds? They could then systematically vary the pH of a single compost/soil mix by using different amounts of lime or acid, and measure the growth of lettuce seeds.

What is the effect of physical factors (e.g., air flow) on peak temperatures achieved in soda bottle composting?

Exploratory Research: Students could build soda bottle bioreactors with various passive and active aeration systems, moisture conditions, and insulation, and then measure the temperatures during composting. Upon comparing their results, they might conclude that the hottest temperatures were achieved by using 5–cm thick foam insulation and passive aeration.

Controlled Experimental Research: Students might recognize that because they varied both the insulation and aeration system at the same time, they could not determine from their exploratory research which factor was more important in promoting high temperatures. They could design a new experiment to compare the effect on temperature of several different thicknesses of insulation, keeping aeration and all other variables constant. Alternatively, they could compare the effect on temperature of several different aeration systems, keeping insulation and all other variables constant.

Often, research projects can be readily converted to technological design projects. In the example discussed above, students researched the effect on compost temperature of various soda bottle bioreactor designs. Another possibility would be to turn this into a technological design project by asking the students to design the most effective or hottest soda bottle reactor.

INTERPRETING RESULTS

Many people are under the impression that research always reveals definitive answers to the questions that are asked. In reality, many research projects only partially answer the original questions. Sometimes, as mentioned above, the original question was not defined well enough. Often, the researchers discover that their methods were inadequate and need to be refined. For example, in trying to determine the effect of moisture content on compost temperature, it might turn out that the range of moisture contents was too narrow to show any effect, and a broader range should be used in a subsequent experiment. Other times, something goes wrong with the experimental procedure. For example, a continuously recording temperature device may stop working in the night, or a custodian might move an experiment.

Even when everything goes according to plan, the results of an experiment may not turn out as expected. A researcher might ask whether adding sawdust or newspaper to vegetable scraps results in higher temperatures in two-can bioreactors. S/he might use five garbage cans with sawdust and five with newspaper. What if the results come out like this?

Trial #	Maximum Temperature (°C)	
	Compost with Sawdust	Compost with Newspaper
1	21.4	26.3
2	26.0	29.9
3	20.2	25.0
4	25.7	15.2
5	18.6	15.8
Mean	22.4	22.4

Can you draw any conclusions? At first, you might say that there are not any differences between newspaper and sawdust because the mean temperatures are the same. This may be true, but by stopping at this point, you may miss some important possibilities. If you examine your results more closely, you will notice that in the first three trials, the newspaper mix produced higher temperatures, and all of them ranged between 25°C and 30°C. But what happened with the last two trials? Was something different? Was the newspaper mostly glossy and colored instead of black and white? Was there a difference in the vegetable scrap mixture? Asking questions about what may have led to discrepant results is fundamental to conducting research. It can often lead to new questions, and in turn, new experiments. It can also help you to redesign an experiment to answer your original question. Carefully examining and using all your results, whether or not they support your original hypothesis, is an essential part of conducting research.

FINAL WORDS

In sum, research is both a cumulative and iterative process. Each experiment builds on what the researcher already knows from reading, talking with other scientists and carrying out previous investigations. And, many experiments lead to refining of the original questions and methods; an experiment may have to be repeated in slightly different form several times before a question is answered. Finally, the results of an experiment, even when seemingly ambiguous or contradictory, often lead to new insights, new questions, and new investigations.

Similar to research, teaching is a process of trying new things and building on past experiences. And, similar to composting, not all the answers are known about how best to engage students in inquiry-based science. We have presented what is currently known about composting science, as well as the experiences of teachers and scientists involved in developing composting research projects suitable for high school students. Continued research and classroom experience will help us to refine composting methods and to develop new ways for students to "learn science as science is practiced." You and your students can be part of this process.

Best wishes on your journey!

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[1] For a thorough discussion of student research, including dependent and independent variables, treatments, and replicates, see Cothron, J. H., R. N. Giese, and R. J. Rezba. 1993. *Students and Research: Practical Strategies for Science Classrooms and Competitions*, 2nd ed. Kendall/Hunt, Dubuque, IA.