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Raphanus sativus, Germination, and Inquiry: A Learning Cycle Approach for Novice Experimenters

by

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Outcomes	Background Knowledge	Lesson	Student Pages

Introduction

Seeds hold the potential for plants and the power to excite children's curiosity. Despite rapid scientific and technological advances, people still marvel at the germination of seeds. This article describes a learning cycle activity sequence that enables fourth-grade children to improve their inquiry ability and develop their understanding of factors influencing seed germination.

Manipulating variables and observing the effects are natural extensions of children's innate curiosity. Open-ended investigations—where children choose a problem, design and conduct an experiment, and analyze and communicate the results—catalyze children's curiosity. The active involvement of children in these experiments provide experiential bases for discussions of the nature of science (Lederman, 1998).

This article describes open-ended experiments with seeds from the common garden radish (*Raphanus sativus*). In numerous research studies, learning cycle approaches have been shown to be effective in achieving a variety of educational goals (Lawson, Abraham, & Renner, 1989). The phases of the 5-E learning cycle, Engagement, Exploration, Explanation, Extension, and Evaluation, guide this activity series. A synthesis of these phases is presented by the Miami Museum of Science.

Problem with problems

In open-ended experiment, children may have difficulty choosing problems that can be translated into hands-on science experiments or solved with the time and resources available (Biddulph, Symington, & Osborne, 1986; Keys, 1998). A teacher who underestimates this difficulty may wind up with students who are confused and frustrated.

The importance of the ability to choose solvable problems extends beyond classrooms. From the work of Alfred Hershey and Martha Chase to Walter Reed, history is replete with examples of scientific advancement from scientists who chose problems that they *could* solve. Einstein recognized the importance of selecting problems when he said,"The formulation of a problem is often more essential than its solution" (Einstein & Infeld, 1938).

While problem generation can be a hurdle to open-ended experiments, the temptation to give children the problem should be avoided as it denies opportunities of creativity, choice, and ownership. A better strategy is to provide a partial problem that prompts students to select a variable to investigate. In the Exploratory Phase of this experiment, children choose a variable to complete a problem statement. Then they design and conduct their experiments.

Techniques drive inquiry

While science drives technology, an important understanding of the nature of science is that technology also drives science (National Resource Council, 1996). The use of the microscope, telescope, particle accelerators, and gel electrophoresis exemplify techniques and technology influencing scientific experiments. Providing techniques for inquiry in classrooms promote open-ended experiments. In the Engagement Phase of this activity series, students learn a technique for germinating radish seeds and observing the seedlings. Then in the Exploration Phase, they apply this technique to an experiment of their choice.

Time and material concerns

Staer, Goodrum, and Hackling (1998), in a survey of lower secondary school teachers, found 99% and 84% of the respondents thought time constraints and material demands, respectively, were significant barriers to open-ended laboratory work. To be sure, the nature of this type of learning environment requires more time and frequently more equipment. However, wise use of time and materials remain important considerations.

Teachers are concerned with classroom time, in part, because of demands to cover content. Because the experiences embedded in this learning cycle address both important inquiry and content standards, the classroom time used may be considered well spent.

Inquiry takes time, as students choose problems, design experiments, obtain materials, conduct experiments, gather data, communicate results, and discuss their experiments. While there are no quick solutions to time concerns, this learning cycle seeks to minimize time demands. The context of inquiry is focused; students choose a variable to investigate and then they begin designing experiments using a learned technique. This scaffolding structure helps novice investigators be more focused and efficient in decision-making and design. The 24-hour germination of radish seeds means data collection can begin one day after setting up the experiment.

This learning cycle uses simple materials to germinate radish seeds. The teacher supplies petri dishes (or other suitable containers), absorbent paper, eyedroppers, and radish seeds. Radish seeds can be inexpensively bought, especially when purchased in bulk or as clearance items from discount stores. To make the open-ended experiment process more manageable for the teacher, the students supply the treatments they wish to investigate.

Grade Level

These experiments are targeted for grade 4 students. They may also be appropriate for students in higher grades.

Objectives and Proficiencies

Process: Students will develop the abilities to

- choose a problem to investigate
- design an experiment
- conduct an experiment and gather data
- analyze data and communicate results

National Science Education Content Standard A: Science Inquiry. As a result of activities in grades K-4, all students should develop abilities necessary to do scientific inquiry.

Content: Students will develop the abilities to

- describe germination
- describe factors that influence germination
- describe factors that do not influence germination

National Science Education Content Standard C: Life Science. As a result of activities in grades K-4, all students should develop understanding of the characteristics of organisms, life cycle of organisms, and organisms and environments

Background Knowledge

Teacher

In this learning cycle, students develop an understanding of seed germination and factors that influence it. In germination–the growth of a young plant from a seed–the plant embryo resumes growth after a period of dormancy. Seeds need oxygen, water, and proper temperatures to germinate.

Other factors may also affect seed germination. Some seeds need their tough seed coats altered to become penetrable by water. This natural process is simulated through the agriculture technique of scarification. In their period of dormancy, seeds may need exposure to cold temperatures. In agriculture this is replicated through the process of stratification.

Prior knowledge and experience will influence the variables fourth grade children investigate. Thus, it is far more likely for children to choose to investigate the effects of a favorite beverage on germination rather than scarification or stratification. It is appropriate for children to choose experiments of interest to them. As they learn more about the process of germination their experiments will increase in sophistication.

Learning about seed germination is an intended outcome of this learning cycle. The most important outcomes, however, are abilities necessary for scientific inquiry. It is important to realize that scientific inquiry is not learned in one lesson or one learning cycle, rather a variety of experiences over time seem essential (Padilla, Okey & Dillashaw, 1983). Teachers should have an understanding of the difficulty fourth-grade students have with open-ended experiments. Choosing a problem for an experiment can be difficult (Biddulph, Symington, & Osborne, 1986). Planning steps in an experiment can be difficult especially because they probably are not formal thinkers (Padilla, Okey, & Garrard, 1984).

Some confusion may occur with the use of the term "variables." Factors that may influence seed germination become independent variables when tested in an experiment. The effects on dependent variables are observed, while other potential variables are controlled. To avoid confusion for the children, the model teacher scripts and student handout do not use the term. If the students are familiar with the term, the teacher will certainly want to use it. If students are not familiar with the term, these experiments will provide concrete experiences to understand what the term means.

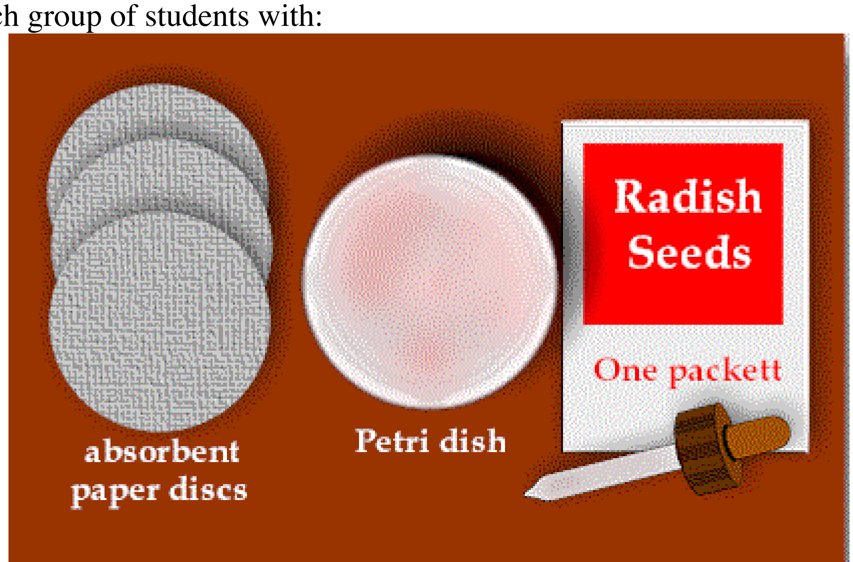
Student

This activity series can be used with children who have little or no experience designing and conducting their own experiments. Students should have an understanding that a problem is a question that guides an experiment. Students consider factors that may affect seed germination. They select one factor and use it as a treatment in an experiment. Comparing the treatment group to the control group facilitates an evaluation of the treatment.

Germination rates are compared, so students need to know how to calculate percent. Students do not need to have any specific knowledge of germination in order to embark on this learning cycle.

Materials List: The teacher should supply each group of students with:

- 2 polystyrene petri dishes
- Masking tape or wax pen to label petri dishes
- Absorbent paper such as paper towels, coffee filters, or filter paper
- Beaker with water
- Eyedropper
- Approximately 50 radish seeds
- Scissors (if absorbent paper needs to be cut)



Safety:

In this open-ended activity, students think about methods to treat seeds and then bring the treatment or treated seeds to school. Before materials are brought to school, teachers should ensure that they are not dangerous or illegal for a minor to possess. During the activities, care in the use of scissors should be exercised. Since water and other liquids are in use, students should be cautious of slippery floors.

Lesson Body

Engagement

In the initial engagement, the teacher displays a radish plant with a bright red radish. Through question asking and statements the teacher creates interest in the upcoming experiences. The following teacher script is offered as one possibility:

(Holding up radish plant) Who can tell us what this is? Where did it come from? What is a seed? Many gardeners like to grow radishes because after you plant the seeds you can have radishes in as little as 28 days! I know somebody who planted 100 seeds and only had four radish seeds sprout or germinate. What percent germinated? Why do you think such a small percent germinated? Today I am going to show you a way to observe the germination of radish seeds and find what percentage germinates.

Teacher divides class into groups of two to three students and distributes Student handout "How Rad!". Teacher demonstrates the following steps.

1. Cut the absorbent paper to make three discs that fit inside the petri dish.

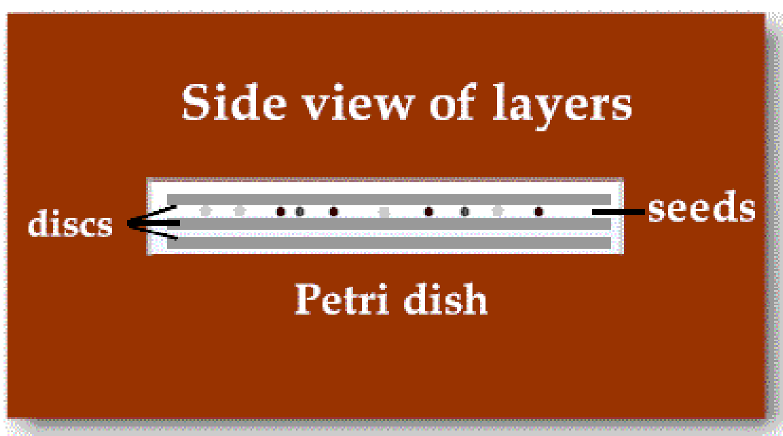
2. Decide how many common radish (*Raphanus sativus*) seeds, from 1 to 20, you wish to try to germinate. Write the number.

3. Put your group's name and the date on the petri dish.

4. Place two absorbent paper discs into the bottom section of the petri dish.

5. Spread the radish seeds on top of the paper discs and place the third paper disc on top of the seeds.

6. Using the eyedropper, add water drop-by-drop until the bottom discs of absorbent paper are completely wet but not flooded. Record how many drops of water you added.



7. Put the cover on the petri dish and leave undisturbed.

After one day students examine their radish seeds and write their observations. After two days the students reexamine their radish seeds. They describe what happens in germination. They record how many seeds germinated and calculate the percent germination.

A large data table is put on the class board or an overhead projector. A sample table is shown below. Students from each group complete their row of the table.

Group	Water Added (drops)	% Germination	Observations
1.			
2.			

3.			
4.			
5.			
6.			
7.			
8.			

Through question asking the teacher elicits student definitions of germination. Students explain how they calculated the percent germination and compare the percent germination of different groups. Students are asked to describe problems they encountered and possible solutions to these problems. For example, perhaps they didn't add enough water drops and the absorbent paper completely dried.

This concludes the Engagement Phase. Admittedly, this Engagement Phase is longer than in many other learning cycles. Within the Phase there are components of Engagement, Exploration, Explanation, and Evaluation, which reflects the non-linear design of the learning cycle. These events are part of the Engagement Phase because they set the context for open-ended experiments in the Exploration Phase and Elaboration Phases.

Exploration

Day One: The teacher will now lead the students to choose a problem to investigate, design an experiment, conduct the experiment, gather data, and communicate the results. The following sample teacher script shows one possible way to begin.

In our germination activity we saw that different groups had different percentages germinate. In nature, under some conditions you may have a high percent germination. In other places you may have a lower percentage or no germination. There are conditions or factors that may influence the germination of seeds. What are some of these conditions? You are going to choose a factor or treatment and see how it affects the germination of radish seeds. Your first task will be to decide which factor you will investigate and complete the following problem statement.

What is the effect of **______________________** on the germination of *Raphanus sativus?*

Your group is responsible for the treatment in your experiment. So whatever it is you choose, you must bring it in or treat your radish seeds at home with this factor. It cannot be anything that is dangerous or illegal for you to have in school.

After you decide on a problem, design an experiment to answer the question. Be specific in details. For example, how many radish seeds will you use? How will you know if the radish seeds germinated? What will you use for a control group? How much fluid will you use? How will you label your experiments? Bring your problem statements and your experiment plans to me when they are complete. Remember to bring in your treatment or treated seeds tomorrow!

Day Two: Teacher provides students time to set up their experiments. When groups finish setting up their experiments, pair them up and have the groups explain their experiments to each other. One group makes predictions on the outcome of the other group's experiments.

Day Four: Students analyze their experiments. They record quantitative data to help them answer their problem statement. They also record supplemental qualitative data.

Explanation

This phase begins with each group explaining what they investigated, how they conducted their experiment, and what they found. Students can discuss similarities and differences in experiments. The teacher asks students to explain problems they encountered with their experimental designs. Perhaps some groups did not have enough information in their experimental designs and they had to decide the procedure as they conducted the experiments.

A large data table is put on the class board or an overhead projector. A sample table is show below.

Group	% Germination Control Group	% Germination Treatment Group	Treatment
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			

A student representative from each group enters their group's data into the table. The teacher helps students analyze the data after it is all entered. Under what conditions was the germination rate the lowest? Under what conditions was it the highest? Which treatments seem to have caused a higher percent germination? Which treatments seem to have caused a lower percent germination? Which treatments had little or no affect on germination? Which results were most surprising?

In my experiences with this experiment, the majority of the treatments children investigate (such as fertilizer, coffee, soda, detergent) have either no effects or negative effects on the germination of the radish seeds. For treatments, such as fertilizer and light, children are often surprised that they had no effect. For treatments such as coffee, children do not seem particularly surprised.

Now the conversation can shift into a discussion of the biological content associated with the activity. Lead children to develop a class definition for germination. Prepare a chart, such as the one below, to write a list of factors that the class suspects are essential for germination (e.g., water), do not seem to affect germination (e.g., minerals in soil), or may inhibit germination (e.g., acid pollutants). At this point do not worry if the lists are correct, they can be verified through more experimentation. However, discussion of tentative conclusions is important, especially when data is questionable. This increases the likelihood of future experiments in this area. An interesting question to have students think about is do seeds need light to germinate? For radish plants and most vegetables the answer is no, the seeds germinate under the soil in the dark. But this is not true for all plants. For example, some rain forest seeds do need light to germinate. When there is a break in the canopy and light hits the ground, these seeds germinate. The discussion of factors influencing germination may also develop into a discussion of amounts and concentrations. While a little fertilizer may have no effect on germination, a lot of fertilizer may inhibit germination.

Factors that ______________ germination

seem essential for	do not seem to affect	may inhibit
1.		
2.		
3.		
4.		
5.		

Elaboration

In this Phase, students are once again given the opportunity to choose a problem to investigate and then to design and conduct their experiment. They can choose to germinate seeds in the petri dishes or in another manner, such as planting the seeds in soil. They may focus their experiments on verifying if a factor in a class list is correct or incorrect, or they may decide to investigate a new factor.

In Day One students design the experiment, in Day Two they set it up. Data is collected on Day Four. On Day Four the data and process is discussed in a similar manner to how data was discussed in the Explanation Phase. The discussion of the data may help to modify the class lists of factors affecting germination.

Evaluation

Evaluation and feedback are necessary throughout the activity series. This helps children know if they are on the right track and helps teachers decide where to give assistance. In the Engagement Phase, answers to questions about the radish plant will give the teacher insights into the children' understanding of concepts related to seeds, germination, and plants. In this phase the students calculate the percent germination from a recipe-style laboratory. If the students have difficulty with this the teacher will need to step in and help students.

In the Exploration Phase, students bring their problem statements and experimental design to the teacher. This will allow the teacher to understand the abilities of the different groups. Feedback will help students know if they (a) chose a suitable treatment (b) have sufficient detail in their design, and (c) prepared an adequate experimental design.

Student descriptions of their experiments are an important source of formative data in the Explanation Phase. The class data table and the group lab reports are also important for teacher evaluation and feedback. In the Elaboration Phase similar sources of evaluation information are present as in the Exploration and Explanation Phases. Student answers to teacher questions in the closure are also important for evaluation.

Closure

Teacher asks questions for the class to discuss. Sample closure questions follow.

1. What is germination?
2. How do we calculate the percent germination?
3. Why was a control group needed in our experiments?
4. What factors are needed for radish seeds to germinate?
5. What things have little or no effect?
6. What pollutants may impair seed germination?
7. What is the most interesting thing you learned from your experiment or a classmate's experiment?

Clean-up

After setting up the experiments, the eyedroppers are rinsed and returned. Extra seeds and absorbent paper are returned. After each petri dish germination, the seeds and absorbent paper are put in the trash. The petri dishes are washed for the next use.

Student Instructions

The following handout is for students. It supplements teacher instructions and information.

How Rad!

experiments by You

Name Date

We are beginning a series of activities studying radish seed germination. You will learn a technique to sprout radish seeds and find the percent germination. Then you will apply this technique to experiments of your choice.

Sprouting Seeds

Procedure

1. Cut the absorbent paper to make three discs that fit inside the petri dish.

2. Decide how many common radish (*Raphanus sativus*) seeds, from 1 to 20, you wish to try to germinate. Write that number here. ______

3. Put your group's name and the date on the petri dish.

4. Place two absorbent paper discs into the bottom section of the petri dish.

5. Spread the radish seeds on top of the paper discs and place the third paper disc on top of the seeds.

6. Using the eyedropper, add water drop-by-drop until the bottom discs of absorbent paper are completely wet but not flooded. Record how many drops of water you added.

____

7. Put the cover on the petri dish and leave undisturbed.

Results

Day One

1. Describe the seeds.

Day Two

1. Describe the seeds

2. How many seeds germinated? _____ How many did not germinate? ______
3. Calculate the percent germination.

Questions

1. What is germination?
2. Jane found that 12 seeds out of her original 15 germinated. What percent germinated?

Exploring: Designing and Conduction Your experiment

In this section you will use the technique for radish germination and apply it to an experiment of your choice. You will design, conduct, and share the results of your experiment.

1. What are some conditions or factors that may affect the germination of a radish seed? Write a list in the space below.

2. Choose a factor you would like to investigate. The factor you investigate will be called the treatment. You need to either bring the treatment or treated seeds to class tomorrow. Make sure your treatment is not a dangerous or illegal. Complete the following problem statement with your treatment:

What is the effect of ___________________________ on the germination of *Raphanus sativus?*

3. Design a control group experiment that will answer the question in your problem statement. Do this in your notebook. Make sure you are specific and include details about the control group, number of seeds used, and how much of the treatment material you will use. When you are satisfied with the procedure of your group's experiment, write it in the space below. Then bring it to the teacher for approval.

4. Record your observations of the radish seeds in this space below. Calculate percent germination for the treatment and control group. Show your work.

5. What conclusions do you make from your data?

6. Put your data into the class data table. Record other group's data below.

Group	% Germination Control Group	% Germination Treatment Group	Treatment
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			

Expanding Your Experiment

Choose a new problem to investigate. You may investigate a factor from the class list or you may choose a new factor. Design the experiment in the space below. Bring this to the teacher for approval. Remember to bring in your treatment or treated seeds tomorrow.

Problem:

Experiment Design:

Data:

Conclusions:

Summary Questions to answer after examining data for the entire class

1. What factors appear necessary for germination?
2. What factors appear to have no influence?
3. What factors lower germination rates?

End of Student Pages

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