



Independent Duckweed Investigations to Review the Scientific Method

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Editor's notes:

Website URLs listed in this resource were current as of publication, but may now be obsolete. If you know of a replacement URL, please suggest it in the resource's "Comments" section.

Safety Note: Students are asked to bring chemicals from home to test their plants, the teacher will need to review safety precautions for those items brought into the classroom.

Disclaimer:

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Independent Duckweed Investigations to Review the Scientific Method

Teacher Section

Purpose

The purpose of this activity is to provide students the opportunities to apply the scientific method in a classroom investigation and understand inquiry lab skills while learning about duckweed, *Lemna minor*, and the ecology of duckweed.

Objectives

Upon completion of this activity the students will be able to:

- To develop a hypothesis in the If/then format.
- Design an experiment to test an environmental factor on duckweed growth.
- Explain the independent and dependent variables in an investigation.
- Demonstrate how to derive a conclusion based on their data.
- Create a poster showing the results of their experiment.
- Discuss some environmental concerns in regards to duckweed.

Grade Level

This lab was designed for high school Biology students and could be adapted for junior high life science classes.

National Science Education Standards

K-12 Unifying Concepts and Processes

Evidence, models and explanation
Change, constancy, and measurement

Grades 9-12:

Science as Inquiry

Abilities necessary to do scientific inquiry
Understandings about scientific inquiry

Life Science

Matter, energy & organization in living systems

Science in Personal & Social Perspectives

Population growth

Natural resources

Environmental Quality

History and Nature of Science

Science as a human endeavor

Nature of scientific knowledge

Prior Knowledge

- Students need basic experimentation skills, or it will need to be reviewed before this activity. This investigation was originally used at the beginning of the school year to review scientific method. However, it could be used any time during the year, after students have gone over the scientific method.
- This also serves as an introduction to ecology and can be adapted or incorporated to demonstrate many ecological principles.
- Students will need to have a working understanding of how to use computers to complete the Internet search.

Time Required

This lab will take 2-3 days to introduce and set up; the independent investigation should continue at least 2 weeks. Allow 5 minutes at the end of class 3-5 times during the investigation for students to take data. An additional 1-2 days are needed for the students to take final data, determine conclusions, make posters and present their posters to the class.

Including All Students

This activity addresses different learning styles with visual and hands-on activities. The use of technology for Internet searches and for data procurement, if available, is good for many students. Plant life affects all students as well as all life on earth and this activity serves as a good jumping-off discussion of ecology. Students can create their investigation based on their own personal experiences. Applications to environmental and agricultural jobs will be of interest to many students and could lead to classroom speakers from these fields. Students can bring in some materials from home and look for duckweed in their environments. Students can investigate different cultural approaches to living with duckweed as both a benefit and pest in the environment.

Questions to Ask Along the Way

- Does each experimental group have enough water in their containers to last over the weekend?
- Are you treating the control group exactly like the experimental group for the length of the investigation?
- Are you taking quantitative and qualitative data? Are the fronds increasing or decreasing in number? Are the fronds green, yellow or white? Does it matter what the water looks like? Is the water clear, cloudy or green? Is there anything else living in the water?
- Is a digital camera helpful to record data and conditions?
- Should you be taking water quality data at the same time?? What kind of data?

Materials

For every lab group (2 students to each group)

- Duckweed cultures and plastic spoons
- Distilled water to start student cultures
- Containers for student cultures (for example, plastic Petri dishes, small snack cup containers, small plastic containers with lids, fruit fly culture vials, and small plastic/Styrofoam cups)
- Labels
- Magnifying glasses
- Duckweed: Observations/Brainstorming sheet
- Chemicals for testing effects on duckweed growth (see following list, keep under fume hood)
- Pipettes and small metric rulers
- Pre-approval Investigative Protocol sheet for brainstorming experiment
- Poster board and markers
- Computer and Internet access
- Data acquisition tools: thermometers, pH meter, CBLs, HOBO data loggers, etc. (each tool should be demonstrated to class and protocols reviewed)

Teacher Section

For each student

- KWL chart
- Internet Search worksheets
- Rubric sheet for posters
- Graphing homework sheet
- Handout on determining duckweed growth

For class

- Digital camera, pH paper and pH meter, and thermometers
- Under the hood, dispenser bottles of: detergent, fertilizer, rubbing alcohol, insecticide, salt water, sugar water, etc.

Safety

- Students should demonstrate and abide by all regular safety policies established in the classroom. Students must turn in their signed safety contract before they can participate.
- Chemical safety should be reviewed on each chemical made available to the students. Students should wear goggles during the use of any chemicals. If any chemicals get on students hands they should immediately wash with soap and water. Chemicals should be left under the fume hood for dispersal.
- It is important to survey students on possible allergies before they are allowed to be exposed to the materials. Gloves, surgical masks and alternate assignments should be available for students with medical concerns.
- Extra care must be taken if students are allowed to bring in materials for testing.
- Suggestions: All materials from home must be brought directly to the science class at the beginning of the day. Students should be told specifically that illegal products (anything alcoholic and any controlled substances) can NOT be used. Rubbing alcohol, insecticide, pesticide and even some medicines can be brought in for testing if students get pre-approved by their teacher and have parental consent.

Preparation

- Duckweed (*Lemna minor*) can be purchased from a scientific supply house. The duckweed cultures should be grown through the summer so they are available at the beginning of school. If you have a lake or pond near your school you can use a net to start a culture by dipping some of the duckweed and placing in water. Duckweed is easy to culture in a pan or aquarium and grows well with regular tap water. Make sure the culture has a daily supply of light. A small amount of fertilizer does speed up the growth. The culture can be started with one small 2 gallon aquarium with distilled water. Every few weeks divide the cultures in half and add half to another small aquarium. You can continue dividing the cultures until you have one aquarium for each class period.
- A week before the lab, ask students to bring in small containers to conduct their individual investigations.
- Under the fume hood: Make testing solutions, label with concentrations and identifications. Concentrations could be in percentages or molarities. This part can be as involved or as simple as the teacher wants to make it. For simple measurements: label the solutions in percentages and have students measure the solutions added to their investigations as number of pipette drops added to experimental groups.
- Suggestions for teacher prepared solutions: rubbing alcohol (10%), acetone (5%), soap solution, salt solution (5% and 50%), fertilizer solution, insecticide solution, acid solution, base solution and a sugar solution.

- Make a transparency on how to determine duckweed growth and showing the labeled parts of a duckweed plant. A good source for information and images is the Missouri Botanical Garden's web site: "Measuring Duckweed Growth" (<http://www.mobot.org/jwcross/duckweed/duckweed-measuring-growth.htm>). You will use the transparency during Part III: Explore.

Procedure

Part I: Engage

- Review the scientific method by discussing data that requires measurement with metric units and qualitative data. Discuss that students will form investigation teams of 2-3 students to do a long-term study. Tell the students that their evaluation will be based on a poster demonstrating their use of the scientific method and their conclusions. Inform them that they will give a classroom presentation on their poster. Tell students that they will be able to bring in supplies, if pre-approved by the teacher, and that they will need to bring containers that can hold water. They will need to bring containers for a control and an experimental group. (35 minutes)
- Have students get in their investigative teams of 2-3 students. Give each team a small plastic container and a small plastic spoon. Let one of the students from each team go to an aquarium and remove 10 duckweed plants. Let one student pick up the Duckweed: Observations/Brainstorming sheet. Have students list 10 observations they can make on the duckweed plants. Then have the team brainstorm 10 things that they might be able to investigate or do an experiment on with the plants. Draw and label that parts of one duckweed plant on the overhead. Groups will turn in paper for grade. (10-15 minutes)

Part II: Explore

- Distribute a KWL Chart to each student (included in Student Section). Have students fill out the K (what they Know about duckweed already) and the W (what they Want to know about duckweed) sections. (10 minutes)
- As a class, discuss what students already know and make a list on the overhead.
- Pass out the Internet Treasure Hunt (in Student Section). Students will have approximately 45 minutes to complete this section. Turn in at the end of class.

Part III: Elaborate

- Using the duckweed transparency, show students how to count duckweed. Put 10 plants in a plastic Petri dish and show on an overhead projector. Illustrate how to count the fronds.
- Have students get into their investigative groups and decide on their independent research project on using duckweed. Groups should use the Pre-Approval Investigative Protocol Sheet. Groups will write down the steps of the scientific method and complete a materials needed sheet. This sheet must be approved by the teacher BEFORE they can start on the experiment. All groups are required to start their experiments on the next day. If groups want to bring in supplies to test they must have pre-approval and the supplies should be brought directly to the science classroom first thing in the morning. If groups do NOT bring in pre-approved supplies, they will set up their experiment with supplies provided by the teacher.

Teacher Section

- Give each investigative team the rubric that will be used to evaluate student posters (in Student Section). Discuss how to measure data, how to record data on graphs and charts and discuss replications and duplications. Give students 20- 30 minutes to set up their experiments. Provide different areas of the room for different class periods to set their experiments up. Make sure students clearly label all their experiments.
- Over the next two weeks, give students 5 minutes at the end of class every couple of days to check their experiments, add water, if necessary and take data. Groups need to make sure there is enough water in the containers over the weekend to prevent the plants from drying out. If an experiment dries out, the group can still make a report and poster and explain what happened in their conclusions. If you have a digital camera, groups can take pictures during the investigation.

Part IV. Evaluate

- At the end of the two weeks, student investigative groups create posters using the poster rubric as a guide.
- Students will do oral group presentations to the class. Teacher should guide discussion with the class about each group's use of the scientific method. Comparisons and contrasts can be made.
- When all groups have presented have a class discussion to complete the L of the KWL chart.

References and Resources

Duckweed Websites:

- "The Charms of Duckweed"
(<http://www.mobot.org/jwcross/duckweed/duckweed-charms.htm>)
- "Tips for Growing Duckweed"
(<http://www.mobot.org/jwcross/duckweed/growing-duckweed.htm>)
- "Duckweed Used in Bioremediation"
(http://www.mobot.org/jwcross/duckweed/practical_duckweed.htm#Bioremediation)
- "Population Growth" (http://www.teachersdomain.org/9-12/sci/life/eco/lp_popgrowth/)
- "Human Influence on Ecology"
(http://www.teachersdomain.org/9-12/sci/life/eco/subtopic_human.html)

For making transparencies:

- "Duckweed Images" (<http://www.mobot.org/jwcross/duckweed/duckpix.htm>)
- "Measuring Duckweed Growth"
(<http://www.mobot.org/jwcross/duckweed/duckweed-measuring-growth.htm>)
- "Common Duckweed"
(<http://www.fcps.k12.va.us/StratfordLandingES/Ecology/mpages/duckweed.htm>)

Publications:

- Abdulayef, D. A. 1969. "The Use of Common Duckweed as Green Feed for Chickens." *Uzbekskii Biologicheskii Zhurnal* (USSR) 13(3): 42.
- Buddhavarapu, L. R. and S. J. Hancock. 1991. "Advanced Treatment for Lagoons Using Duckweed." *Water Environment & Technology*, Water Pollution Control Federation. March 1991: 41-44.
- Culley, D. D., and E. A. Epps. 1973. "Uses of Duckweed for Waste Treatment and Animal Feed." *Journal of the Water Pollution Control Federation* 45(2): 337-47.
- Harvey, R. M., and J. L. Fox. 1973. "Nutrient Removal Using Lemna Minor." *Journal of the Water Pollution Control Federation* 45(9): 1928-38.
- Hillman, W. S., and D. D. Culley. 1978. "The Uses of Duckweed." *American Scientist*. 66(July): 442-51.
- Joy, K. W. 1969. "Nitrogen Metabolism of Lemna minor: Growth, Nitrogen Sources and Amino Acid Inhibition." *Plant Physiology* 44: 842.
- Landolt, E. ed. 1980. "Key to Determination, Cytological Variation; Amino Acid Composition and Sugar Content." In *Biosystematic Investigations in the Family of Duckweeds (Lemnaceae)*, vol. 1, no. 70. Publication of the Geobotanical Institute of the E.T.H. Zürich: Stiftung Rübel.
- _____. 1986. *The Family of Lemnaceae - A Monographic Study: Morphology, Karyology, Ecology, Geographic Distribution, Systematic Position, Nomenclature, Descriptions*. (vol. 1 of monograph). In *Biosystematic Investigations in the Family of Duckweeds (Lemnaceae)*, vol. 2, no. 71. Publication of the Geobotanical Institute of the E.T.H. Zürich: Stiftung Rübel.
- Landolt, E., and R. Kandeler. 1987. *The Family of Lemnaceae - A Monographic Study: Phytochemistry, Physiology, Application, and Bibliography*. (vol. 2 of monograph). In *Biosystematic Investigations in the Family of Duckweeds (Lemnaceae)*, vol. 4, no. 95. Publication of the Geobotanical Institute of the E.T.H. Zürich: Stiftung Rübel.
- Lueoend, A. 1983. "Growth of Duckweeds (*Lemnaceae*) Depending on Nutrient Supply, Especially Phosphorous and Nitrogen." In *Biosystematic Investigations in the Family of Duckweeds (Lemnaceae)*, vol. 3, no. 80. Publication of the Geobotanical Institute of the E.T.H. Zürich: Stiftung Rübel.
- Mbagwu, I. G., and H. A. Adeniji. 1988. "The Nutritional Content of Duckweed (*Lemna paucicostata* Hegelm.) in the Kainji Lake Area, Nigeria." *Aquatic Botany*. 29: 357-66.

Duckweed: Observations/Brainstorming

Student names _____

Make 10 observations about the duckweed plants.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

Brainstorming

Discuss and brainstorm 10 things that you might use duckweed for in an experiment.
What are some things that you might investigate?

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

Draw and label a duckweed plant.

Student Section

K W L

Name _____

What do you know about duckweed?		
What I already <u>K</u> now...	What I <u>W</u> ant to know...	What I <u>L</u> earned...

Duckweed Investigation Internet Treasure Hunt

Name: _____

This web info search will help you find information about what duckweed is and how it is used in scientific research. It is important to find the information as well as to consider the author(s) point of view, purpose of creating the website, and whether you feel the information is accurate.

1. What is Duckweed?		
URL	Site 1: http://www.mobot.org/jwcross/duckweed/duckweed.htm	Site 2: http://www.unl.edu/agnicpls/wqduckweed.html
Who created this web site? (company, organization, etc.)		
Why did they create it? Check all that apply	<input type="checkbox"/> To provide factual information <input type="checkbox"/> To influence the reader's opinion <input type="checkbox"/> To sell a product or service <input type="checkbox"/> I'm not sure	<input type="checkbox"/> To provide factual information <input type="checkbox"/> To influence the reader's opinion <input type="checkbox"/> To sell a product or service <input type="checkbox"/> I'm not sure
How credible (accurate) do you think this info is?	<input type="checkbox"/> Very accurate <input type="checkbox"/> Somewhat accurate <input type="checkbox"/> Not very accurate <input type="checkbox"/> I'm not sure	<input type="checkbox"/> Very accurate <input type="checkbox"/> Somewhat accurate <input type="checkbox"/> Not very accurate <input type="checkbox"/> I'm not sure
What did you learn? Give at least 3 things from each site.	1. 2. 3.	1. 2. 3.

Student Section

Internet Treasure Hunt, contd.

2. How is duckweed used in industry?

URL	Site 1: http://www.mekarn.org/sarec03/hanghue.htm	Site 2: http://www.mobot.org/jwcross/duckweed/practical_duckweed.htm
Who created this web site? (company, organization, etc.)		
Why did they create it? Check all that apply	<input type="checkbox"/> To provide factual information <input type="checkbox"/> To influence the reader's opinion <input type="checkbox"/> To sell a product or service <input type="checkbox"/> I'm not sure	<input type="checkbox"/> To provide factual information <input type="checkbox"/> To influence the reader's opinion <input type="checkbox"/> To sell a product or service <input type="checkbox"/> I'm not sure
How credible (accurate) do you think this info is?	<input type="checkbox"/> Very accurate <input type="checkbox"/> Somewhat accurate <input type="checkbox"/> Not very accurate <input type="checkbox"/> I'm not sure	<input type="checkbox"/> Very accurate <input type="checkbox"/> Somewhat accurate <input type="checkbox"/> Not very accurate <input type="checkbox"/> I'm not sure
What did you learn? Give at least 3 things from each site.	1. 2. 3.	1. 2. 3.

3. Is Duckweed good or bad for the environment?

URL	Site 1: http://www.environmentallevantage.com/Duckweed.htm	Site 2: http://www.mobot.org/jwcross/duckweed/duckweed.htm
Who created this web site? (company, organization, etc.)		
Why did they create it? Check all that apply	<input type="checkbox"/> To provide factual information <input type="checkbox"/> To influence the reader's opinion <input type="checkbox"/> To sell a product or service <input type="checkbox"/> I'm not sure	<input type="checkbox"/> To provide factual information <input type="checkbox"/> To influence the reader's opinion <input type="checkbox"/> To sell a product or service <input type="checkbox"/> I'm not sure
How credible (accurate) do you think this info is?	<input type="checkbox"/> Very accurate <input type="checkbox"/> Somewhat accurate <input type="checkbox"/> Not very accurate <input type="checkbox"/> I'm not sure	<input type="checkbox"/> Very accurate <input type="checkbox"/> Somewhat accurate <input type="checkbox"/> Not very accurate <input type="checkbox"/> I'm not sure
What did you learn? Give at least 3 things from each site.	1. 2. 3.	1. 2. 3.

Student Section

Internet Treasure Hunt, contd.

4. How do I do a research project with Duckweed?			
URL	Site 1: http://www-saps.plantsci.cam.ac.uk/osmos/os5.htm		Site 2: http://www.mobot.org/jwcross/duckweed/education.htm
Who created this web site?			
Why did they create it? (check all that apply)	<input type="checkbox"/> To provide factual information <input type="checkbox"/> To influence the reader's opinion <input type="checkbox"/> To sell a product or service <input type="checkbox"/> I'm not sure		<input type="checkbox"/> To provide factual information <input type="checkbox"/> To influence the reader's opinion <input type="checkbox"/> To sell a product or service <input type="checkbox"/> I'm not sure
How credible (accurate) do you think the info is?	<input type="checkbox"/> Very accurate <input type="checkbox"/> Somewhat accurate <input type="checkbox"/> Not very accurate <input type="checkbox"/> I'm not sure		<input type="checkbox"/> Very accurate <input type="checkbox"/> Somewhat accurate <input type="checkbox"/> Not very accurate <input type="checkbox"/> I'm not sure
URL	Site 3: http://www.bottlebiology.org/investigations/terraqua_observe.html		
Who created this web site?			
Why did they create it? (check all that apply)	<input type="checkbox"/> To provide factual information <input type="checkbox"/> To influence the reader's opinion <input type="checkbox"/> To sell a product or service <input type="checkbox"/> I'm not sure		
How credible (accurate) do you think the info is?	<input type="checkbox"/> Very accurate <input type="checkbox"/> Somewhat accurate <input type="checkbox"/> Not very accurate <input type="checkbox"/> I'm not sure		
What did you learn? Give at least 3 things from each site.	Site 1: 1. 2. 3.	Site 2: 1. 2. 3.	Site 3: 1. 2. 3.

Pre-Approval Investigative Protocol Sheet

Names _____

Your Lab Title: _____

Problem: Each group starts with the same problem, today we are investigating...
What are some factors that effect duckweed growth?

Hypothesis (If/then):

If _____ (what you are testing) effects the growth of
 duckweed, then the growth will _____ (increase or decrease)
 with the treatment of _____ (amount or concentration used).

Materials needed:

What data do you think you will gather?

How will you measure this data?

What do you think will happen?

Will you be bringing any materials or supplies in for the investigation?

Teacher approval _____

Counting Duckweed Fronds:

- The leaves of the duckweed are small and flat; new leaves will bud off of the larger ones. The plants will usually have one to two larger fronds.
- Look at the leaves using a microscope to count the fronds, new budding leaves off of the main leaves should be counted.

Counting Leaves:

- Count and record the number of leaves on each plant.
- Count every visible leaf on the plant, including the tips of new leaves just beginning to emerge. Record any observations on changes or differences in plant color.

The following internet site has more information and specific drawings as a guide.
<http://www.mobot.org/jwcross/duckweed/duckweed-measuring-growth.htm>

Duckweed Investigation: Poster Rubric

Making A Poster: Design an Experiment, the Scientific Method

CATEGORY	4	3	2	1
Title and Labels	Title can be read from 6 ft. away and is quite creative.	Title can be read from 6 ft. away and describes content well.	Title can be read from 4 ft. away and describes the content well.	The title is too small and/or does not describe the content of the poster well.
Steps of the Scientific Method	The poster includes all steps of the Scientific Method as well as additional information.	All steps are included on the poster.	All but one of the steps are included on the poster.	Several required elements were missing.
Content - Describe how each step is used	All steps are explained on the poster.	Less than 4 steps are explained on the poster.	Less than 3 steps are explained on the poster.	Less than 2 steps are explained on the poster.
Graphics - Relevance All data is shown and graphs or charts are used.	All graphics are related to the topic and make it easier to understand.	All graphics are related to the topic and most make it easier to understand.	All graphics relate to the topic.	Graphics do not relate to the topic.

Poster Rubric, contd.

CATEGORY	4	3	2	1
Conclusion - During presentation, explanation of the successes and the problems	The project described and explained in detail. Hypothesis answered and problems identified. Changes for replications suggested.	Three of the components discussed Description/ explanation. Hypothesis identified. Identified problems. Changes for future.	Two of the components discussed Description/ explanation. Hypothesis identified. Identified problems. Changes for future	One of the components discussed Description/ explanation . Hypothesis identified. Identified problems. Changes for future.
Use of Class Time	Used time well during each class period. Focused on getting the project done. Never distracted others.	Used time well during each class period. Usually focused on getting the project done and never distracted others.	Used some of the time well during each class period. There was some focus on getting the project done but occasionally distracted others.	Did not use class time to focus on the project OR often distracted others.

Presentation of poster to class 6 Pts.

Total pts possible 30 Pts.

Self evaluation Pts.

Points given by teacher Pts.