What's Wrong in Waterville?

COLLECT EVIDENCE ● ESTABLISH LINKS ● MAKE AN ARGUMENT

An exploration in water quality, experimental design, and implementing solutions designed for elementary learners.

TEACHER COPY

Biotechnology Outreach

Table of Contents

BE A SCIENTIST

- ✓ Listen to and read instructions closely
- ✓ Follow all directions, including safety precautions
- ✓ Wear appropriate safety equipment, including medical gloves
- ✓ Collaborate with your team/group to ensure all work is done efficiently and correctly
- ✓ Take time to think about…
    - …WHAT you're doing.
    - …HOW you're supposed to do it.
    - …WHY you're doing it.

Thank you for choosing the BOEC!

EQUITABLE LEARNING:

Our promise…
This innovative collection of curriculum modules has been developed with a focus on promoting students' access to learning. While teachers will need to deploy context-specific instructional strategies to ensure skillful implementation of any science experience, we have considered these key points during curriculum development:

Students build understanding through carefully sequenced learning
The storyline approach to sequencing learning experiences allows for a diverse range of pedagogical nuances that are often absent from "textbook" curriculum materials. Introducing a relevant, meaningful problem (phenomenon) before students have learned core ideas can improve the chances that students will learn transferrable knowledge and skills (National Research Council, 1999). The curriculum modules contained in this booklet build on one another and help students find meaning in each investigation that leads them closer to making sense of the anchor phenomenon.

Students use scientific practices to make sense of a phenomenon
Through the purposeful use of hands-on investigations, students will engage with many of the NGSS Science and Engineering Practices. This engagement will help them to connect what they are learning to problems that impact their own family and community. By doing so, students may be driven to use those discoveries to help solve issues of global significance. This leads them to better understand scientific ways of thinking and to value science in greater ways (National Research Council, 2012).

Students' own questions and wonderings drive learning
Activities presented in this curriculum unit are designed to encourage student-student discourse. These academic conversations provide teachers valuable insight into student thinking and provide evidence that can be used to guide the next instructional steps. By eliciting students' questions and helping them use their own funds of knowledge to make sense of relevant phenomena, teachers support student motivation and agency (Harris, Phillips, & Penuel, 2011).

Introduction

As schools and educators have strived to incorporate more science, technology, engineering, and mathematics (STEM) learning into their classrooms, much of that effort has been focused on middle and high school learners. Many educators believe that scientific learning does not impact students until they are adolescents, but research has demonstrated that elementary students have often already made up their minds about science before they begin middle school. Because of this, it is critical that young learners participate in meaningful scientific experiences.

The Waterville storyline represents the BOEC's first foray into the world of elementary learning. This curriculum was developed with a variety of influences, including Iowa State University Department of Education faculty, pre-service elementary educators, NGSS standards, and current ISU research. We hope that the efforts put into this project have culminated into a meaningful experience for educators and students alike.

In this curriculum, elementary students are both empowered and challenged to encounter a phenomenon, construct an explanation, and design a solution. Students work with a team of water quality scientists to investigate the issue of the fish population in the pond by Franny's Farm. As the activities progress, students learn about the relationship between fertilizer runoff and aquatic ecosystem health. They are then challenged to design an experiment to test the efficacy of different water quality improvement techniques for nitrate removal. Lastly, students work with their groups and the imaginary town to implement the best solution to meet the town's needs and budget.

The concepts of water quality are influenced by the research of Iowa State scientist Dr. Michelle Soupir. Dr. Soupir joined ISU in 2008 as a researcher in the Biosystems Engineering Department to develop more sustainable water systems. Her research focuses specifically on woodchip bioreactors, which use woodchips to culture nitrogen-fixing bacteria. These bacteria are capable of transforming nitrogen runoff from agricultural fields into nitrogen gas, which helps prevent water pollution on a local and global scale. Rivers and lakes with high nitrate concentrations experience eutrophication, which is the process of a body of water losing its oxygen due to the increased growth of algae on the surface. Without the dissolved oxygen, fish and other organisms cannot survive.

Dt. Soupir's laboratory investigates how we can maximize the effectiveness of bioreactors while still keeping them cheap and manageable for farmers. In 2013, they installed two pilot-scale woodchip bioreactors at Iowa State's Engineering Research Farm.

These pilot-scale reactors allow her lab to investigate the effects of different variables on a smaller scale than the full-sized bioreactors that would be used on a farm. These bioreactors have proven to be a simple and effective solution for reducing the nitrate load from farmland. Students will learn more about bioreactors and Dr. Soupir's research in their efforts to find a solution in Waterville.

In addition to woodchip bioreactors, students will explore other water purification methods, including filters and activated carbon. After testing all three of these potential solutions, students come together to decide what option is best for the town. The evaluation process incorporates engineering design strategies for students, challenging them to consider multiple factors in their decision of what is best. Throughout this curriculum, students will gain a deeper understanding of the scientific process, how to carry out a scientific experiment, and how to effectively design and implement solutions.

As you go through this curriculum booklet, note that this curriculum strives for versatility in the standards and practices that are covered. In the following pages, the NGSS Standards and Tenets of Effective STEM Education will be explained more in-depth. Each activity is aimed at covering a variety of NGSS Standards, which allows teachers to choose which ones to emphasize to meet their classroom needs. The NGSS connections are fully laid out on Page 9. Additionally, the activities are designed to incorporate more than just scientific learning. It is especially important for elementary students to see how science interacts with other learning disciplines, so clear connections to mathematics and literacy were included. If teachers desire, the first and last activities can take on an expanded mathematical role, with more calculations and measurements conducted to explore the differences in fish populations and to best implement the solution. The case studies were designed to challenge students to read scientific articles and summarize findings. We hope that the cross-discipline learning opportunities empower students and make incorporating this curriculum in your classroom more attainable.

Finally, this curriculum was designed with elementary educators in mind. Research has demonstrated a disconnect between elementary teachers and confidence in STEM content, and we hope that these activities act as a guide for future scientific experiences. Using the tenets described on the next page, teachers can incorporate STEM learning in their classroom in ways that are both engaging to students and intuitive to the educator. When elementary students can view their teachers as co-learners, science flourishes! We hope this curriculum inspires and empowers you to do just that.

The Tenets of Effective STEM Education

In addition to the NGSS standards, this curriculum was designed to incorporate the Tenets of Effective STEM Education for Identity Development. The tenets are a set of research-based pillars to guide scientific experiences to maximize engagement and ultimately encourage young learners to become more passionate about science. The tenets are divided into two categories: culture and curriculum. The curriculum tenets describe characteristics of the activities and learning done in the classroom. The Waterville curriculum focuses heavily on outlining the scientific process using differing fish populations in ponds as the central phenomenon; additionally, it strives to be adaptable by including literacy and mathematics components, as well as a variety of NGSS standards. The culture tenets focus on the aspects of learning that the classroom and district must provide. Students should feel that they are represented in the learning that they do and that their social identities matter to the rest of the class. Collaboration is critical for developing and refining scientific practices. Lastly, teachers should feel empowered to teach science by the resources and knowledge provided by the BOEC and by the support of their school district and students.

When these tenets are put into practice, scientific curriculum becomes engaging, meaningful, and inspiring. We hope that the Waterville curriculum serves as one of many opportunities for the young learners in your classroom to experience science in an exciting and empowering way.

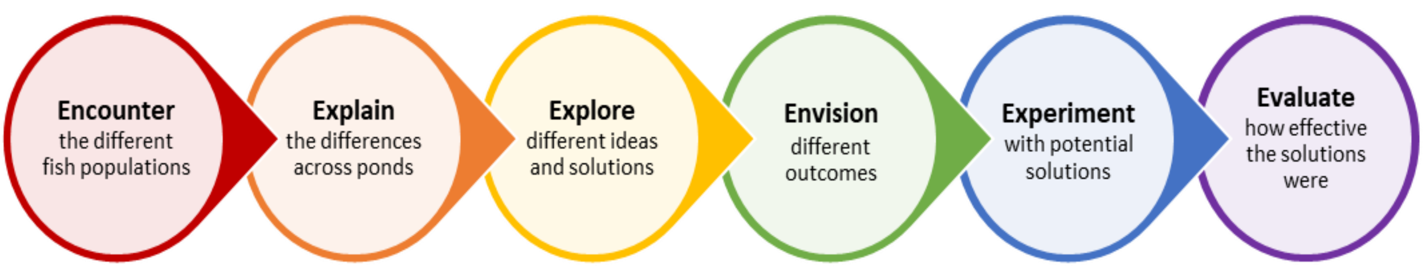
Tenets of Effective STEM Education for Identity Development			
Culture	**Social Sensitivity**	**Collaboration**	**Teacher Empowerment**
	-STEM identities cannot be built effectively without first recognizing the social identities of students. -Teachers recognize the intersection of socioeconomic status and access to STEM education. -Students feel comfortable expressing their identities and how they connect to scientific phenomena. -Students feel learning reflects their identity.	-Teachers encourage collaboration among students to construct explanations and find solutions. -Teachers emphasize collaboration as a central facet of the scientific process. -Students believe that they possess knowledge or skills that make them valuable and essential members of an experiment. -Students feel included and cared for in STEM classrooms.	-Teachers feel that they have the resources, experience, and knowledge to teach STEM curriculum effectively. -Students look to teachers as scientists and sense-makers, and not just a source of knowledge. -Teachers have access to professional development or other programs to learn how to implement STEM content effectively. -Teachers can see impact of effective STEM content across disciplines.
Curriculum	**Process Emphasis**	**Central Phenomenon**	**Adaptability**
	-Science is not presented as a static body of facts and theories, but rather a dynamic process of making sense of the world. -Results and academic grades are de-emphasized, and the process of science itself is made out as the goal. -STEM curriculum presents a problem to be solved and the framework and resources to solve it independently. -Curriculum empowers and inspires students to investigate.	-STEM experiences are driven by a central phenomenon that students find interesting and relevant. -Phenomena inspire students to ask questions and design experiments to ultimately find an explanation; the explanation is not simply given. -STEM curriculum can easily and coherently be tied back to a phenomenon.	-STEM curriculum can be modified to best meet the needs of students and teachers. -Standards and goals of curriculum are clearly communicated to students and can change to meet their desires. -STEM educators feel confident in connecting curriculum to a variety of SEPs, CCCs, and even other content areas.
Tenets inspired by Carlone, Scott, and Lowder and the National Academies of Science, Engineering, and Medicine.			

Suggested Learning Schedule

The table below gives a suggested outline for how the activities can be ordered. Each activity has been designed to take approximately 30-40 minutes, but can be shortened to meet classroom needs. These activities do not need to be done on consecutive days, especially once the experiments have been set up. We recommend a minimum of two days of data collection prior to the town hall, but more can be added. Two optional case studies are also included. While not essential to the curriculum, you may find that the case studies provide real-world applications for your students and may help them prepare for constructing an argument at the town hall.

Monday	Tuesday	Wednesday	Thursday	Friday
Day 1	Day 2	Day 3	Day 4	Day 5
Day 6	**Case Study***	**Case Study***	Day 7	Day 8

Each day is centered around one step of the scientific method and is aimed at immersing students in the process. For the sake of this curriculum, we look at the scientific method as the Six E's: Encounter, Explain, Explore, Envision, Experiment, and Evaluate. By structuring the curriculum this way, each day builds upon itself; while the days don't need to be consecutive, continuity is critical! We encourage you to be explicit with your students about where they are in this process. Helping them understand how the scientific process builds upon itself is a huge aim of this curriculum.



NGSS Connections

The standards seen outlined here should be considered as POSSIBLE connections. Depending on how each module and activity is implemented, teachers may choose to emphasize additional or different science and engineering practices, disciplinary core ideas, and cross cutting concepts beyond those indicated below.

	Science and Engineering Practices								Disciplinary Core Ideas				Cross Cutting Concepts						
	Asking Questions and Defining Problems	Planning and Carrying Out Investigations	Analyzing and Interpreting Data	Developing and Using Models	Constructing Explanations and Designing Solutions	Engaging in Argument from Evidence	Using Mathematical and Computational Thinking	Obtaining, Evaluating, and Communicating Information	Physical Science	Life Science	Earth and Space Science	Engineering, Technology, and Applications	Patterns	Cause and Effect	Scale, Proportion, and Quantity	Systems and System Models	Energy and Matter: Flows, Cycles, and Conservation	Structure and Function	Stability and Change
Day 1	X		X				X			X				X	X				X
Day 2	X		X		X					X	X			X			X		X
Day 3	X	X			X			X		X	X		X	X					X
Day 4		X			X	X				X	X	X		X					X
Day 5		X						X		X	X			X		X			X
Day 6		X	X					X		X				X		X			X
Case Study 1						X		X		X	X		X	X			X		X
Case Study 2						X		X		X			X	X					X
Day 7		X	X					X		X				X		X			X
Day 8			X		X	X		X		X	X	X		X					X

Waterville Storyline

A Plan for Student Learning

Anchoring Phenomenon
Low fish quality in the pond by Franny's Farm

Driving Questions
What factors affect water quality?
How can we prevent and improve low water quality?

Phenomenon-Driven Lessons	Making Sense (Learning)	Connection with Next Investigation
What is water quality?	Water quality refers to the potential contaminants or other solutes present in a body of water, which impacts how a body of water can sustain life.	Contamination from outside sources deteriorates water quality.
How is water quality maintained?	Multiple water quality improvement methods are used throughout the town, including filters, bioreactors, and activated carbon.	Water quality can be improved through human intervention.
What is a hypothesis?	A hypothesis is a testable scientific prediction.	Students need to develop a hypothesis before they can test their solution.
How are investigations carried out?	Students learn more about experimental design and different variables.	Proper experimental techniques are critical for producing usable results.
What factors need to be considered when implementing a solution?	Students must consider financial and ecological impacts of their solution.	**Solving environmental issues requires research, experimentation, and careful implementation.**

Welcome to Waterville!

Day 1: Encounter

Overview: This activity introduces students to the curriculum's anchor phenomenon: what's wrong with the pond at Franny's Farm? Students will "fish" at various ponds around the imaginary town and use a variety of resources to evaluate the quality of the fish populations at each pond.

Students will…

- …use tools to evaluate the health of the fish populations at each pond.
- …analyze the data collected to make an argument about the differences in population quality.
- …begin to question why the ponds might by different.

Time Required: Approximately 30 minutes

Materials Needed

- ✓ Waterville town map
- ✓ Four fishing rods
- ✓ Four fish populations (Use fishing manual on page 14 for fish sizes)
  - Lively Lake: 8 fish (2 rose, 5 blue, and 1 green)
  - Secret Spot: 8 fish (2 rose, 3 blue, and 3 green)
  - Playful Park: 8 fish (2 rose, 4 blue, and 2 green)
  - Franny's Farm: 6 fish (5 rose, 1 blue, and 0 green)
    - Note: The rose fish at the farm should be 1.5 inches, and the tail of the blue fish should be cut just a little short.
- ✓ Rulers
- ✓ Student investigation notebooks

Teacher Tips

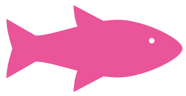
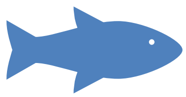
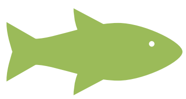
- Monitor groups closely to make sure participation and communication is as even as possible.
- If desired, student roles can be assigned, like fisher, recorder, and measurer, and students can rotate through each job.

Activity Procedure

1. Roll out Waterville town map in an accessible part of the classroom. In each lake, pour out the matching fish population.
2. As a bellringer or warm-up, have students reflect on their previous experiences in fishing or what a healthy pond looks like.
3. Divide students into 4 teams.
4. Play the introductory video.
5. After students finish the introduction, hand out the materials needed to go fishing.
6. Assign each group to one pond.
7. Have students take turns fishing until all of the fish in the pond are caught.
8. Students should analyze their catch by recording the number of each species caught and measuring each fish. Students should also record if each fish is larger, smaller, or equal to the average length in the fishing manual.
9. After the data is collected, students should share their pond's data as a large group. Record the number of fish caught, the number of species observed, and the number of fish equal to or greater than the mean length.
10. When everyone has shared, have groups discuss if they noticed any trends in the data.
11. Ask each group which ponds they think are the healthiest and which are the least healthy.
12. Once each group has shared, have students spend the remaining time reflecting on what the differences between the healthy and unhealthy ponds might be. Encourage them to use the town map and their previous real-life experience to come up with answers.
13. Let students know that they will learn more about the ponds in the coming days, so it's okay that they don't have the answers at the end of today's activity.

Student Takeaways: At the end of this activity, students will identify that Franny's pond contains a lower-quality fish population. Additionally, each group should have questions and ideas about what might be causing the differences.

Student Fishing Worksheet

Species Photo	Name	Habitat Facts	Average Size
	Rose Fish	Lives in any pond or lake	2 inches
	Blue Gill	Lives best in cleaner water	4 inches
	Green Fin	Lives only in clean water	3 inches

Pond:_______________ **Total Fish Caught:**________

Species	Number Caught	<, =, > than average
Rose Fish		
Blue Gill		
Green Fin		

How many were greater than or equal to the average? ______

Workspace:

What is Water Quality?

Day 2: Explain

Overview: Students learn more about what water quality is and what could possibly be affecting the pond by Franny's Farm. By comparing the water qualities and conditions of each pond, students should arrive at the conclusion that Franny's fertilizer might be the cause of the issue.

Students will…

- …analyze water quality data using testing strips.
- …compare and contrast different ponds to identify potential problems.
- …construct an explanation for why Franny's Farm has lower water quality.

Time Required: Approximately 30 minutes

Materials Needed

- ✓ Waterville pond water samples
- ✓ Water quality testing strips
- ✓ Character interviews

Teacher Tips

- Encourage students to rely on previous knowledge and to bounce ideas off of each other. Today's activity is designed to be built towards, not taught!
- Your curiosity as a teacher is critical for this step. Ask questions to your students to inspire learning!
- Do what you need to have student connect the nitrogen fertilizer at Franny's Farm to the high nitrate concentration at the pond. This conclusion is extremely important for the rest of the curriculum.

Activity Procedure

1. Use the labeled containers to create water samples around the room prior to the activity or during reflection time.
    a. The samples from Playful Park, Lively Lake, and the Secret Spot should contain only tap water.
    b. The water sample at Franny's Farm should be a solution made by adding 10mL of nitrate solution to a liter of tap water.
2. Have students return to their groups from yesterday's activity. Spend a few minutes reflecting on what we learned yesterday, especially the final conclusion:
    a. What pond had the worst fish?
    b. What could be causing that?
3. Ask students what they know about water quality.
    a. How can water be made better or worse? Take a few minutes to brainstorm previous knowledge.
4. Play the video introduction to the Waterville lab and water quality.
5. Have each group rotate around the room to test each water sample. Students should record the values in their investigation notebook.
6. When students return to their desks, ask them if they have noticed any trends between the quality of each water sample and the fish populations from yesterday.
7. Give students about 5 minutes to brainstorm what could be causing the differences in water quality.
8. Hand out character interviews. Let students read through each one.
9. Each team should fill out the final question for Day 2 in their notebook: what is causing the differences at Franny's Farm?
10. Have students discuss their explanations as a large group.
11. Once students reach a conclusion, end the activity with a brief reflection of what they have learned and how this problem could possibly be solved.

Student Takeaways: Students will collect data and use it to identify why the fish populations vary at each pond. Using literacy skills, students will identify potential sources of contamination for Franny's pond. Students will come up with an idea as a class, and then brainstorm ideas for how the problem can be solved.

Student Water Quality Worksheet

What do the Waterville scientists say that water quality is?

How can water quality be made better or worse?

	Playful Park	Lively Lake	Secret Spot	Franny's Farm
Nitrate (ppm)				
pH				
Chlorine (ppm)				

What could be causing the difference in water quality at Franny's Farm?

What Can We Do?

Day 3: Explore

Overview: Students begin to explore potential solutions for preventing nitrate runoff at Franny's Farm. Students will brainstorm ideas on their own, and then watch videos/read about how water quality is improved. Once they are done exploring ideas, they will make predictions about how effective each method could be at Franny's Farm.

Students will…

- …brainstorm solutions based on the explanations they made in the previous activity.
- …use a variety of sources to understand how different methods of water purification work.
- …make predictions for how each method would work as a solution for this water quality problem.

Time Required: Approximately 30 minutes

Materials Needed

- ✓ Prediction worksheet
- ✓ Benchtop-scale models of each method
    - **NOTE:** Woodchips are not included in the materials sent by the BOEC; you'll need to find a spot at your school where you can "borrow" some.
- ✓ Water quality testing strips

Teacher Tips

- Once again, relying on previous knowledge is important! Encourage students to think about how water might be improved in the tap water they drink or at a public pool.

Activity Procedure

1. Before class starts, set up the benchtop-scale models of each water purification method around the classroom. Use the labeled containers to set up the following:
    a. Playful Park: Add 1 bag (100g) of activated carbon. Fill the rest of the way with tap water.
    b. Lively Lake: Add 1 bag (50g) of sand and 1 (50g) of gravel. Fill the rest of the way with tap water.
    c. Waterville Lab: Add about 100g of woodchips. Fill the rest of the way with tap water.
    d. Secret Spot: Fill a container with tap water.
2. Have students return to their groups from yesterday's activity. Spend a few minutes reflecting on what was learned yesterday, especially the final conclusion.
3. Lead a brainstorming session with students about potential solutions for water purification (or removing the nitrates/preventing nitrate runoff).
    a. How does water get purified at their home? At a pool?
4. After brainstorming, play the video for the scientist descriptions of what water purification means.
5. Allow students a few minutes to write a definition and any ideas in their reflection space in the student notebook.
6. Have students rotate around the room to each model. At each station, there will be a few handouts where students can read more about each method.
7. In their groups, have students fill out the reflection page in their investigation notebooks. Students should make a prediction about how effective each method would be for Franny, and then rank each method at the end.
8. If time allows, lead a class wide discussion about what methods students predict to be the most effective.

Student Takeaways: Students will use prior background knowledge, videos, and models to learn more about water purification. Students will make predictions about how different techniques would work at Franny's Farm.

Student Water Purification Worksheet

Location: Playful Park

- Water Quality Improvement Method: ______________________________
- Do you think this would work for Franny's Farm? Why or why not?

____
____
____
____
____

Location: Lively Lake

- Water Quality Improvement Method: ______________________________
- Do you think this would work for Franny's Farm? Why or why not?

____
____
____
____
____

Location: Secret Spot

- Water Quality Improvement Method: ______________________________
- Do you think this would work for Franny's Farm? Why or why not?

____
____
____
____

Location: Waterville Lab

- Water Quality Improvement Method: ______________________________
- Do you think this would work for Franny's Farm? Why or why not?

____
____
____
____
____

Rank each method by how well you think it would work at Franny's Farm.

1. ____
2. ____
3. ____
4. ____

Explain your ranking. Predict what might happen at the pond if Franny used your #1 method.

____
____
____
____
____
____
____

Why Would It Work?

Day 4: Envision

Overview: This activity focuses on hypothesis development. Students will learn what a hypothesis is, why it matters, and how they are used in a scientific experiment. Using the information they have learned so far, they will make a formal hypothesis for the experimental method they will be testing. Students will also begin to design their experiment.

Students will…

- …learn why hypotheses are important for an experiment.
- …write a formal hypothesis for their experiment.
- …design their experiment and identify variables.

Time Required: Approximately 30 minutes

Materials Needed

- ✓ Hypothesis Machine worksheet
- ✓ Lab-O-Matic worksheet

Teacher Tips

- Keep all materials used so far on display for students to revisit concepts from previous lessons.
- Although students should brainstorm ideas as a group, encourage them to write their hypothesis and reasoning in their own words.
- Remind students about the glossary in the back of their booklets if they need help with a word.

Activity Procedure

1. Start the activity in a large group. Ask students what they know about hypotheses. Let students brainstorm and share their thoughts for a few minutes.
2. Students will watch a brief video that describes how the Waterville lab uses hypotheses in their work. This video outlines what a hypothesis is as well as the parameters of the experiment will be.
    a. Students will use desktop-scale versions of the activated carbon, woodchip bioreactor, and water filter methods.
    b. From these options, students will predict which will work best as their claim and back it up using the data they've collected so far.
3. Students should use the claim-evidence-reasoning model described in The Hypothesis Machine worksheet to map out their ideas.
4. As a group, students should make their final hypothesis for their experiment. Students should also identify what the results will look like if their hypothesis is supported or rejected.
5. Students should also begin to design their experiment using the Lab-O-Matic included in their investigation notebook. In the Lab-O-Matic, students will identify the independent variable, dependent, and controls. They will also describe their control sample.
6. If time allows, have students share their hypotheses with the class. Do the students agree on what they expect to happen? Make sure their predictions tie back to what will happen to water quality and the fish population at Franny's Farm.

Student Takeaways: Students will learn what a hypothesis is and why it matters to scientists. Using the Hypothesis Machine structure, students will learn to write a meaningful hypothesis. Students will learn more about experimental design and the variables to consider. At the end of the class period, each group should have a hypothesis for the most effective method for Franny's Farm and the reasoning to back it up.

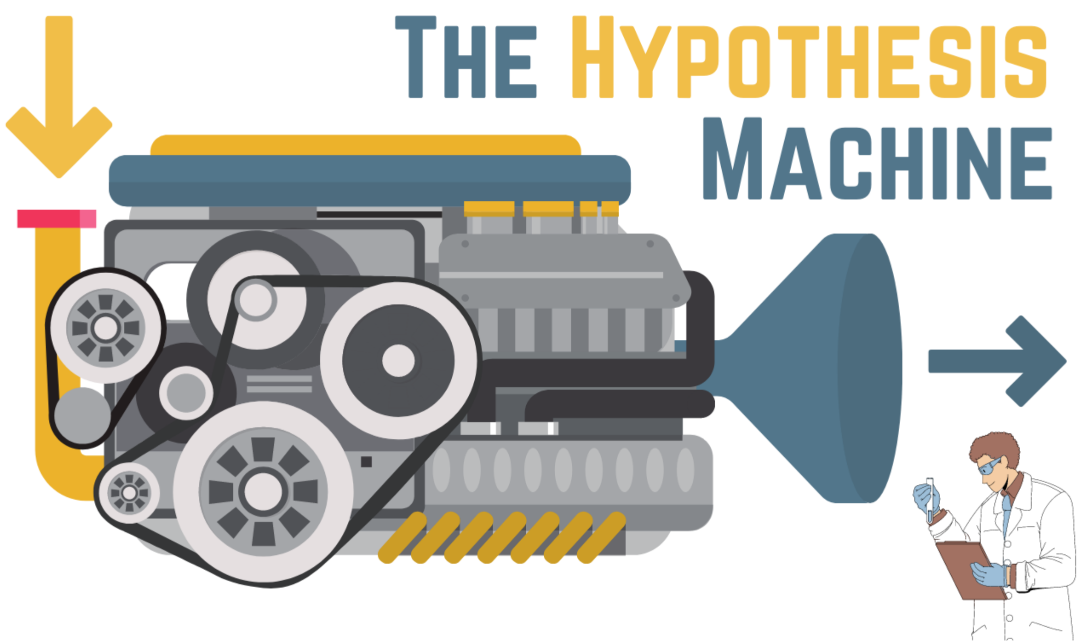
Student Hypothesis Worksheet

NAME: ______________

Evidence

\+

Reasoning



Claim

Student Lab-O-Matic Worksheet

HYPOTHESIS

What is your hypothesis? Which method do you think will work best and why?

PREDICTION

What will the results look like if your hypothesis is supported?

What if it's not supported?

CONSTANTS

What parts of the experiment need to be kept the same?

EXPERIMENT DESIGN

What problem does the experiment solve?

What is being measured, or the **dependent variable**?

What is being changed, or the **independent variable**?

What should we use as a **control**?

How Can We Test It?

Day 5: Experiment

Overview: In this activity, students will set up the experiment they designed on Day 4. Each group will construct a control sample, filter, bioreactor, and activated carbon chamber. They will also take baseline measurements and predict what will happen throughout the rest of the experiment.

Students will…

- …construct an experiment based on their designs.
- …collect data to be used for later analysis.

Time Required: Approximately 30 minutes

Materials Needed

- ✓ 50ppm nitrate solution
- ✓ Syringes, caps, and dropper cups
- ✓ Bioreactor Syringe: woodchips and cotton ball/filter paper
    - **NOTE:** Woodchips are not included in the materials sent by the BOEC; you'll need to find a spot at your school where you can "borrow" some.
- ✓ Activated Carbon Syringe: activated carbon and cotton ball/filter paper
- ✓ Filter Syringe: sand, gravel, and cotton ball/filter paper
- ✓ Water testing strips
- ✓ Colored pencils (optional)

Teacher Tips

- Wait to hand out materials until students have read through the instructions.
- Safety gear won't be necessary to conduct this experiment, but you may find it adds to the scientific ambience!
- We recommend only teachers handle the nitrate solution to prevent spills.

Activity Procedure

1. Break students into their small groups. Have them finish (if needed) and review their experimental design and predictions from Day 4.
    a. Have they changed or expanded on any of their ideas since then?
    b. Do they have any questions about the experiment ahead?
2. Give each team 4 syringes and dropper cups. Using a test tube rack, stand each syringe upright with a dropper cup underneath.
3. Display the construction instructions slide for each trial syringe one by one. Have students gather the supplies for each trial as they construct it. Make sure all of the syringe tips are capped during the filling!
4. Once their syringes are filled, add the nitrate solution to each one.
5. Have the students use the drawing page in their booklet to draw each of their trials while the solution settles in each syringe.
6. While students are drawing, pass out paper towels to each table.
7. Have students uncap the syringes. Make sure students keep the syringe over the dropper cup while uncapping and let the flowthrough drop into the cup below.
8. Once the water has run through all four of the syringes, students should use a nitrate test strip on each sample in the dropper cup. This data can be recorded in Data Collection 1.
9. Cap all four syringes. Pour the flowthrough back into the top of the syringes.
10. Gently press the syringe plungers into the top to cover the syringes to prevent contamination. The plungers should not be pushed in too far, as the bioreactor and activated carbon will produce gas that can lead to the syringe plungers popping off.
11. Store them somewhere at room temperature where they will not be disturbed.

Student Takeaways: At the end of the class, each group will have one control syringe and three experimental syringes. Students will gain a deeper understanding of experimental design.

What Are the Results?

Day 6-7: Experiment

Overview: On Days 6 and 7, students will collect data and begin the analysis process. Data tables and plots are included in the workbook. As students record data, they will also reflect on how their findings compare to their hypothesis and evaluate how their experiment is working.

Students will…

- …collect and record data.
- …analyze data using a line plot.
- …use the data to evaluate their hypothesis and experimental design.

Time Required: Approximately 15-20 minutes each day

Materials Needed

- ✓ Student workbooks
- ✓ Completed experimental set-up
- ✓ 4 different markers/colored pencils for line plot
- ✓ Ruler

Teacher Tips

- Monitor groups closely to make sure participation and communication is as even as possible.
- Encourage discussion and questioning about what the data means and how it relates to the predictions they made previously.

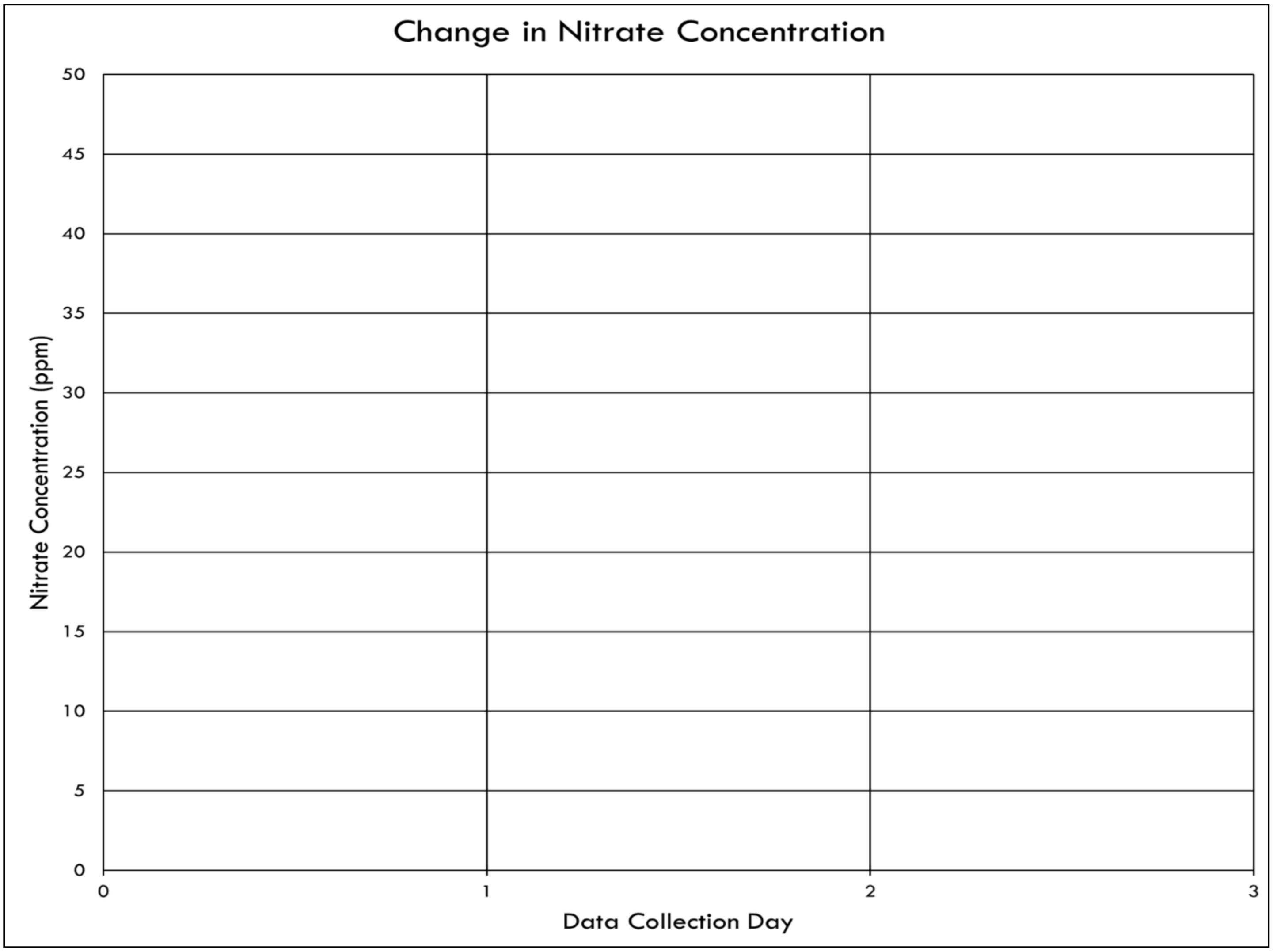
Activity Procedure

1. **On both days**, distribute the appropriate experimental set-ups to each group of students.
2. Once everyone has received their syringes, instruct them to place the dropper cup below the syringes. Once the cup is placed, take the plunger out of the syringe, and then remove the cap.
3. When all of the water has dropped out of the syringe, use a nitrate test strip to find the nitrate concentration in each sample.
4. Data should be recorded in the data table in the student investigation notebook, and then plotted on the line plot.
5. **On Day 6**, have students discuss their findings so far.
    a. Does it align with their predictions so far, or are they surprised?
    b. Could they stop the experiment now, or should they continue it?
6. **On Day 7**, data collection, students should have their data table filled out. Students should use the data to construct a line plot.
7. Use a ruler and the color marked in the key to connect two points at a time on the line plot.
8. With the data collected and the line plot drawn, students should discuss the success of their experiment and evaluate their hypothesis.
    a. Did their findings align with their predictions, or were they surprised by the data?
    b. How could they expand upon this experiment in the future?
9. On the final data collection day, the experiment can be deconstructed. Syringes and caps should be saved. Place the used activated carbon in a Ziploc bag. The dropper cups, woodchips, and filter materials can be thrown away, and the nitrate solution can be poured down the sink.

Student Takeaways: Students will practice effective data collection and analysis using the structured worksheets in their notebooks. Students will also compare their data with their hypothesis to determine if it was supported or rejected.

Student Data Collection Worksheet

Data	Control	Filter	Woodchip Bioreactor	Activated Carbon
0				
1				
2				
3				



Key:

The Gulf Dead Zone

Case Study #1

Overview: The first case study explores the real-life environmental impacts that can occur when nitrate runoff goes unchecked. Students will learn more about the real-world applications of what they're learning and how scientists are working to reduce nitrate pollution. At the end of the case study, students will compare two methods and decide which they think would work better for Franny.

Students will…

- …connect their classroom experiences to real-world issues.
- …learn more about environmental research that is being conducted at Iowa State University.
- …use literacy skills in a scientific context.

Time Required: Approximately 30 minutes

Materials Needed

- ✓ Case Study Journal from https://boec.biotech.iastate.edu/

Case Study Procedure

1. Have each group read through Document A paragraph by paragraph.
2. Answer the questions for Document A.
3. Repeat the process for Document B.
4. Have half of the groups read Document C and the other half Document D.
5. Mix the groups so half have read C and half D. Students should complete the final two worksheets in these groups.

Teacher Tips

- Emphasize the connections between the activities in the classroom and the real-world phenomena.
- Focus on using evidence to construct an argument. The case studies are good practice prior to the final town hall.

The Flint Water Crisis

Case Study #2

Overview: The second case study looks at another case of water quality gone wrong. While the first emphasizes the scientific process and current research, this case study looks at ordinary citizens who stepped up to act as scientists and activists when their local government failed the community. The case study ends with brief presentations from each group on the person that they studied.

Students will…

- …connect their classroom experiences to real-world issues.
- …learn about how science can be used to empower communities.
- …use literacy skills in a scientific context.

Time Required: Approximately 30 minutes

Materials Needed

✓ Case Study Journal from https://boec.biotech.iastate.edu/

Case Study Procedure

1. Assign each group of students one document from B-F.
2. Each team will read Document A and their assigned document.
3. Each student should fill out the questions page.
4. Each team should complete the presentation diagram for the class.
5. Have each team present to the rest of the class.

Teacher Tips

- Emphasize the connections between the activities in the classroom and the real-world phenomena.
- Focus on communicating evidence and deciding what is the most important. This will be good practice for the town hall.
- Presentations can be quick, “read off the page” ordeals.

What Is the Solution?

Day 8: Evaluate

Overview: In the final activity, students need to decide which of their experimental methods is going to best meet the needs of the town. At the town hall session, each team must consider the ecological impact of reducing the nitrate concentration while also balancing the financial restrictions.

Students will…

- …compare the effectiveness of each method with the town's budget to decide the best solution.
- …build an argument using data to explain why they think their solution is the best.
- …implement their proposed solution in the town to maximize its impact.

Time Required: Approximately 30 minutes

Materials Needed

- ✓ Waterville town map
- ✓ Solution stickers
- ✓ Completed data tables and line plots
- ✓ Waterville town budget

Teacher Tips

- Encourage students to talk with each other and ask questions as they go.
- Although formative assessments are not built into the curriculum, Day 8 would be the most effective activity to assess if needed. Student arguments can be evaluated based on how their data is used to draw a conclusion.

Activity Procedure

1. Display the Waterville town hall slides. These slides will explain why Waterville is having a town hall, what needs to be accomplished, and the town's budget for the solution.
2. Using the worksheet on the next page, students should work with their team to construct their proposed solution. Their solution needs to consider the budget, incorporate data from their experimentation, and use evidence from the activities they have completed so far.
3. Once each team has completed the worksheet, each group should explain their solution to the class. Once each group has shared, give each time a moment to reflect.
    a. Did each team have the same idea? If they didn't, why not?
4. At the end of the reflection period, each group should vote on which water-cleaning method to use. If the class is struggling to reach a consensus, allow for more reflection or discussion time as needed.
5. When the class has settled on a final solution, use the appropriate solution sticker and place it where students think it will be most effective. Ideally, it should be the woodchip bioreactor sticker placed somewhere near Franny's farm.
6. Once the sticker has been placed, play the epilogue video. This video is a brief overview of how the student's solution has improved the town.
7. If time allows, there is a final worksheet for students to complete in their workbooks. This worksheet leads students through a reflection on the scientific process and challenges them to think about how their experiment could be built upon in the future.

Student Takeaways: In the final activity, students will consider all of their learning thus far to design the best solution for the town of Waterville. Using their data and the town budget, students should determine a woodchip bioreactor at Franny's Farm is the best solution. Finally, students will reflect on what they learned about science as a practice.

Student Town Hall Worksheet

WATERVILLE TOWN HALL

NAME: ____________________ DATE: ______________

Data

Budget

Evidence

Solution

Works Cited

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