MAINE MUSEUM OF INNOVATION LEARNING + LABOR

Energy Innovation Kit

Teacher's Guide:
Lesson 3

Made possible in part by:

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Introduction

Maine MILL's Innovation Kit program provides lessons and materials to schools throughout Maine designed to inspire them with stories, experiences, and paths for the future. The Energy Innovation Kit focuses on energy innovation, renewables, and solar energy. Students learn about the history of how power was generated in Maine's mills and factories, and how new forms of energy are captured and deployed. They explore electricity, make circuits, and build solar cars. They learn about jobs in the field, including electrician, solar installer, and electrical engineer, and hear from people in these jobs today. Our Energy Information Kit offers teachers 2 weeks (6-8 class periods) of lessons and activities and all the necessary materials to successfully complete each. Each lesson and activity is linked to Maine State Learning Standards and Next Gen Science Standards, where applicable, to help teachers achieve their curricular goals for the year.

How to Use the Energy Innovation Kit Teacher's Guide

The lessons and activities in this kit are designed for students in upper elementary through middle school. Each lesson contains learning objectives, complete instructions for the lesson from set up to closing, assessment tools, and standards. Teacher's have the flexibility to deliver the lessons in sequential order, scaffolding students' knowledge, or they may select individual lessons based on students' past knowledge, experience or ability level. Where appropriate cross-curricular activities, alternate ideas for assessment and lesson alternatives are noted. Materials provided in the kit are only for the lessons provided in this teacher's manual and not for alternate suggested lessons.

Care of the materials in the Energy Innovation Kit

Enough materials have been provided in this kit for 75 students (3 classes of 25 students each). Many activities require students to work in pairs or small groups. All materials in the Energy Innovation Kit are contained in sturdy plastic boxes. Handle the trunk the materials are delivered in with care, it will be heavy. It is recommended that teacher's store materials in a room that can be secured. Each box is labeled with the activity the material is for and a checklist for teachers to use when returning materials to the box. Please note any materials that may have been damaged on the checklist sheet.

Note about Consumable Materials

Lesson 3 contains a selection of consumable materials for students to use in the construction of their model water wheels. Please return any unused materials with the kits to reduce the amount of waste.

Mechanical Energy - Water Wheel STEAM Challenge

Innovation Kit Lesson 3

Time: 2 - 50-60 minute class periods

***Lesson Notes**: There are 2 different options for this activity. Option A is recommended for students under grade 5. Students will test the water wheel's effectiveness based on the number of turns the wheel can make in 15 seconds. Option B offers instructions for having students calculate the work (measured in joules) and power (measured in watts). This option is recommended for grades 5+. Materials for both options are the same and differences in setup and lessons are noted in the sections below.

Learning Objectives:

- Students will design, build and refine a prototype of a functioning water wheel.
- Students will be able to explain the forces involved in the operation of a water wheel.
- Students will be able to observe and collect data about the effectiveness of the water wheel design.
- Students will be able to calculate the rate of rotation for their water wheel (Design Challenge Option A - recommended for students under grade 5)
- Students will be able to calculate the amount of work and power their water wheel design generates (Design Challenge Option B - recommended for students grades 5+)

Materials Needed for Water Wheels:

- Cap with a center hole
- Masking tape*
- Scissors*
- Stopwatch or access to a clock*
- Aluminum dishes
- Small plastic cups
- Pipettes
- Weighing dishes
- Any additional materials the teacher wishes to supply*

*Teachers supply these materials.

Materials Needed for Water Testing Stations:

- binder clips
- plastic pan
- wooden dowel
- String (Option B only)
- paper clip (Option B only)
- hex nuts (Option B only)

Class 1

Set Up

1. Set up a computer with a projector and have the Maine MILL video "Historic Hydropower in Lewiston" ready to show the class.
2. Have enough copies of the Water Wheel STEAM Design Challenge for each student or share this digitally before class begins.
3. This activity works best with students working in groups of 3-4. We have provided enough material kits for 6 groups per class.

Each group will need:

- 1 cap with a center hole
- Masking tape
- Scissors

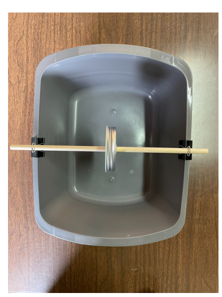
Have a table with the bucket choices set out for students to use. We have provided the following*:

- Small plastic cups
- Pipettes
- Weighing dishes
- Aluminum dishes

*Teacher may choose to supplement with additional material choices.

4. Set up 2 water testing stations for the class to use.
   a. Fasten a binder clip to the center of the long side of the plastic pan. Flip up the metal arm on the inside of the pan and flip the outside arm down.
   b. Insert the ends of the wooden dowels into each one of the flipped up binder clip arms.

STOP HERE FOR OPTION A



Option A

Option B

OPTION B CONTINUE:

   d. Cut a 65cm length of string.
   e. Tie one end of the string tightly 2 cm from the end of the dowel rod on the outside of the binder clip arm so that it may hang freely.
   f. Tie the free end of the string to a paper clip so that the top of the paper clip measures 50 cm from the knot tied around the dowel.
   g. Set the assembled testing station at the end of a table or counter so that the paper clip hangs freely over the edge and the string does not rub against anything. The string should be able to wind up onto the dowel during testing.
   h. Repeat the above steps for the second testing station.

(Set Up Continued for Option B)

i. Weigh 10 hex nuts on a scale to determine the average weight of each nut. Write the average weight in Newtons (N) on paper or notecard next to each testing station.

j. Open the paperclip slightly and attach 5 hex nuts to the paper clip hanging from each testing station dowel. Pinch closed to secure the hex nuts. For the final test of the water wheels, add five more hex nuts to each paper clip for a total of 10.

Note on water source for both Option A and B: For fair testing, water must be at a consistent flow rate. This can be achieved by either using an extendable sink faucet with the flow rate marked on the handle - OR - setting up a support stand with a ring clamp (not provided). Place a funnel in the ring with a stopper. Fill the funnel with water from a pitcher and remove the stopper while continuing to pour water from the pitcher.

Introduction

1. Ask students what they think of when they think of a water wheel. Answers may include references to sawmill style vertical water wheels and turbines. Ask students to recall some of the information they learned about hydropower from the group that presented on that topic during the previous jigsaw activity to review material from the day before -OR- ask students to explain what they know about hydropower, to establish prior knowledge.
2. As a class watch the Maine MILL video "Historic Hydropower in Lewiston." Following the video discuss students' observations and check for understanding. Some questions could include: Why was Lewiston a good choice for building a textile mill? What are some ways that digging the canals impacted the city and the environment? Describe how the canal system helps to power the machinery in the mills.

Instructions, Teacher Modeling, Guided Practice

1. OPTION A: Explain to students that they will be constructing their own water wheel prototype using simple materials. They will then calculate how many times their wheel turns in 15 seconds and see if they can improve upon the design to turn more efficiently (faster) in a second trial. Explain that the axle of a water wheel can be attached to other machinery to transfer the wheel's mechanical energy into useful work like grinding, hammering, lifting and turning powerful machinery, as in the video.

OPTION B: Explain to students that they will be constructing their own water wheel prototype using simple materials that can lift a load. They will then calculate the work done and power generated and they will be given time to make improvements. Explain that the axle of a water wheel can be attached to other machinery to transfer the wheel's mechanical energy into useful work like grinding, hammering, lifting and turning powerful machinery, as in the video.

(Instructions, Teacher Modeling, Guided Practice Cont. for Option B)
Work is defined as the amount of force (measured in newtons) exerted over a distance (meters). A unit of work is the joule (J).

Work (J) = Force (N) X Distance

The faster the wheel turns the more power it produces. Power is the rate at which work is done and is measured in watts (W). One watt is equal to one joule of work per second.

Power (W) = Work (J) / time (s)

Together as a class, complete a few sample calculations. Examples could include:

A teacher lifted a box of books weighing 90 N to the top of a desk that was 0.82m high. How much work did the teacher do?

Two students volunteered to put away lab equipment. They were each assigned to put away spring scales that weighed 10 N. Alyssa's shelf was 1 meter above the table and she put away 10 scales in 1 minute. Marcus's shelf was 0.5m above the table and he put away 25 scales in 90 seconds. Who generated more power?

OPTIONS A & B: Demonstrate for students how to use the water testing stations.

Students will now be given time to create a prototype water wheel. Together as a class read the first portion of the lesson and review directions before beginning.

Independent Work Time and Clean Up

1. Follow the directions on the Water Wheel STEAM Design Challenge sheet.

Teacher tip: circulate throughout the room while students are assembling their water wheels to answer any questions but do allow students ample time to work out how to construct the water wheel independently.

2. Time should be given for each group to test their water wheel in order to ensure that it is functioning properly and to make the necessary adjustments if it is not, so that calculations can be made.
3. Allow time at the end of the class for clean up. Students should store their materials for the next class period.

Class 2

Set Up

1. Each group will need their water wheels from day 1.
2. Water testing stations should be set up.

Instructions, Teacher Modeling, Guided Practice

1. Have students collect their water wheels from the day before and sit with their groups.
2. Review the previous class period and expectations for today's class.

Independent Work Time

1. Students should continue to work through their STEAM Challenge sheets. Time should be given for first test, redesign and second test.
2. If time allows, students should complete the calculations and remaining questions on the STEAM Challenge Sheets.

***Teaching tip:** Circulate around the room during this phase, answer questions and provide guidance when necessary. Ask each group to describe to you the changes they made to the original design and explain how they believe it will improve the design.

Closing and homework

1. Have students clean up all materials.

Materials that must be returned to the kit:

- Binder clips
- Caps with hole
- Hex nuts
- String
- Wooden dowel rods
- Plastic Pans

Please return any unused:

- Aluminum dishes
- Cups
- Paper clips
- Pipettes
- Weighing dishes

All used materials may be recycled or disposed of.

2. Unfinished STEAM Challenge sheets should be sent home for homework to be handed in by the next class period.

Standards

Maine Learning Results

4-PS3-4 Apply scientific ideas to design, test and refine a device that converts energy from one form to another.

MS-PS3-5 Construct, use and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. MS-PS2-2 Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and mass of the object. MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

HS-PS3-3 Design, build and refine a device that works within given constraints to convert one form of energy into another form of energy.

Next Gen Science Standards

4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents. (Grade 4)

MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3 Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4 Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Name: ________________________________

Option A

Water Wheel
STEAM Challenge

Humans have been harnessing the power of water for thousands of years. A water wheel is designed to capture the potential kinetic energy of flowing water and convert it into mechanical energy. As water flows over the wheel with buckets attached to the outside, it fills the buckets with water increasing the weight on one side of the wheel, causing it to turn. The axle of the water wheel can then be attached to other machinery to transfer the mechanical energy of the turning wheel into useful work, like grinding grain, sawing wood or operating looms in textile mills.

You and your team are challenged to use the limited materials provided by your teacher to design a water wheel that turns as efficiently as possible. You will be given a center wheel and you must design what you predict will be the most efficient bucket design.

Step 1 - Planning and Design

Review the materials you have to select from for your bucket design. You may only choose one type of bucket material and you may have a maximum of 8 items of your choice (for instance 8 aluminum dishes or 8 pipettes).

Consider the following questions when planning your design:
Which items will make good buckets?
How many buckets will be attached to the wheel?
Can you modify the buckets to make them work more efficiently?
How can you keep the wheel balanced and turning smoothly?

With your team, draw and label your design below. Also create a list of materials needed.

Materials list:

******Once you have completed your design, you must show it to your teacher before obtaining the materials for construction.******

STEP 2 - Construction

1. Obtain the materials you need to construct your wheel from your teacher.
2. Cut a piece of masking tape that is 5 cm longer than the circumference of your wheel.
3. Press 1 cm of tape onto the outside of the wheel.
4. Fold the tape back so that the sticky side is now facing out and press down. Make sure that your tape is wrapped tightly around your wheel and that you have pressed it down firmly.
5. You may modify your buckets any way you wish if you predict they will work more efficiently. Then attach your buckets to the wheel by pressing firmly onto the tape.

During construction you may find that your initial design needs to be changed. You may do this at any time! Note the changes in your design drawing with a colored pencil.

6. Mark one of the buckets on your water wheel with an X so that it is easy to see when the wheel is turning
7. Take your water wheel to a water testing station.
8. Attach the water wheel to the axle by threading one end of the wooden dowel through the hole in your wheel and move it to the center of the dowel so that the hole fits tightly onto the center of the rubber tube. MAKE SURE YOUR BUCKETS ARE FACING THE RIGHT WAY.
9. Try testing your water wheel 3 times and fill in the chart below. Each test should be 15 seconds long.

Time	Number of turns

STEP 4 - Redesign

Now that you have had a chance to try out your design, consider how you could make it generate more power by turning faster. Using different colored pencil, mark any changes you would like to make to your design on your drawing and modify your water wheel with the change.

STEP 5 - Retest

Try testing your modified redesign at the water testing station and fill in the chart below. Each test should be 15 second long.

Time	Number of turns

Option A

STEP 6 - Evaluation
Use the following to evaluate your team's results.

Fill in the chart below with the information from your water wheel testing. Determine the average amount of turns for each wheel by adding together the total number of turns and dividing by 3.

Test 1 - Original Design		**Test 2 - Redesign**	
Time	Turns	Time	Turns
Average # of turns =		Average # of turns =	

Answer the questions below.

Did you succeed in creating a more efficient water wheel in your redesign? Explain.

What changes did you make to your redesign after you tested it the first time?

Did you choose to use additional materials provided by the teacher to add to your redesigns? Explain.

If you could have had access to materials that were different from those provided, what would your team have requested? Why?

Do you think that engineers have to change their designs during construction of systems or products? Why might they?

If you could do it again, how would you change your design? Why?

What are some of the disadvantages of using a water wheel to produce power?

What are some of the advantages of using a water wheel to produce power?

Name: ________________________________ Option B

Water Wheel
STEAM Challenge

Humans have been harnessing the power of water for thousands of years. A water wheel is designed to capture the potential kinetic energy of flowing water and convert it into mechanical energy. As water flows over the wheel with buckets attached to the outside, it fills the buckets with water increasing the weight on one side of the wheel, causing it to turn. The axle of the water wheel can then be attached to other machinery to transfer the mechanical energy of the turning wheel into useful work, like grinding grain, sawing wood or operating looms in textile mills.

Work is defined as the amount of force (measured in newtons) exerted over a distance (meters). A unit of work is the joule (J).

Work (J) = Force (N) X Distance

The faster the wheel turns the more power it produces. Power is the rate at which work is done and is measured in watts (W). One watt is equal to one joule of work per second.

Power (W) = Work (J) / time (s)

You and your team are challenged to use the limited materials provided by your teacher to design a water wheel that can do the most work and generate the most amount of power possible. You will be given time to design, build, test, calculate results. Then you will be given time to redesign your wheel based on your observations and calculations to try to improve your results.

Directions

Step 1 - Planning and Design
Review the materials you have to select from for your bucket design. You may only choose one type of bucket material and you may have only 8 items of your choice (for instance 8 aluminum dishes or 8 pipettes).
Consider the following questions when planning your design:
Which items will make good buckets?
How many buckets will be attached to the wheel?
Can you modify the buckets to make them work more efficiently?
How can you keep the wheel balanced and turning smoothly?

With your team, draw and label your design below. Also create a list of materials needed.

Materials list:

*****Once you have completed your design, you must show it to your teacher before obtaining the materials for construction.*****

STEP 2 - Construction

1. Obtain the materials you need to construct your wheel and your bucket material choice from your teacher.
2. Cut a piece of masking tape that is 5cm longer than the circumference of your wheel.
3. Press 1 cm of tape onto the outside of the wheel.
4. Fold the tape back so that the sticky side is now facing out and press down. Make sure that your tape is wrapped tightly around your wheel and that you have pressed it down firmly.
5. You may modify your buckets any way you wish if you predict they will work more efficiently. Then attach your buckets to the wheel by pressing firmly onto the tape.

During construction you may find that your initial design needs to be changed. You may do this at any time! Note the changes in your design drawing with a colored pencil.

6. Take your completed water wheel to a testing station. Make sure that the string is hanging 0.5 m from the wooden dowel to the paper clip.
7. Calculate the weight of the load by multiplying the weight of one hex nut by the number on the paper clip. Record the information on the chart below
8. One person should start the timer, while another person starts the water flowing. Stop the timer when the paper clip reaches the dowel. Record in seconds the time it took on the chart below.
9. Unwind the string and repeat the test a second time noting results below.

Weight of load:_____________N **Distance Lifted:___________m**

Trial	Work (J)	Time (s)	Power (W)
1			
2			
Avg.			

Observations:

10. Remove the water wheel from the dowel rod.

11. Calculate the work output for the AVERAGE row above.

Work (J) = Force (N) x Distance

13. Calculate the power output for the AVERAGE row above.

Power (W) = Work (J) / time (s)

STEP 4 - Redesign

Now that you have had a chance to try out your design, consider how you could improve your results so that it could lift 10 hex nuts. Using a different colored pencil, mark any changes you would like to make to your design on your drawing and modify your water wheel with the change. Consider how you could change the size or shapes of your buckets? Could you add or remove buckets? How well balanced is your bucket design?

STEP 5 - Rebuild and retest

Make the modifications to your original design and take your water wheel to a testing station and try testing your changes. Fill in the chart below.

Weight of load:_____________N Distance Lifted:___________m

Trial	Work (J)	Time (s)	Power (W)
1			
2			
Avg.			

Calculate the work output for the AVERAGE row above.

Work (J) = Force (N) x Distance

Calculate the power output for the AVERAGE row above.

Power (W) = Work (J) / time (s)

Compare your results. How did the amount of power generated by the original water wheel design compare to the redesigned model?

Post-Challenge Evaluation
Following the group STEAM design challenge, answer the following questions independently.

1. What changes did you make to your redesign after you tested it the first time?

2. If you could have had access to materials that were different from those provided, what would your team have requested? Why?

3. Do you think that engineers have to change their designs during construction of systems or products? Why might they?

4. If you could do it again, how would you change your design? Why?

5. What are some of the disadvantages of using a water wheel to produce power?

6. What are some of the advantages of using a water wheel to produce power?