Lesson Plan: Getting into Inquiry-Based Learning with Inclined Planes

Curriculum Connections

The activities in this resource complement the Ontario Science and Technology Curriculum (Understanding Structures and Mechanisms: Grade 2, Movement).
http://www.edu.gov.on.ca/eng/curriculum/elementary/scientec18currb.pdf (page 61)

Step 1: Structured Inquiry

Question + Procedure + ~~Solution~~
The structured inquiry process provides students with a question and a procedure to follow, but allows them to discover the solution.

Materials Required:

Teaching Basic Concepts

Use words, pictures, and objects to introduce different types of simple machines:
Lever: scissors, seesaw, tongs, bottle opener, nutcracker, light switch, lower jaw

1. **Inclined plane:** ramp, slide, stairs (stairs are modified inclined planes)
2. **Pulley:** can be observed on a flag pole, some clothes lines, or on a crane
3. **Wheel and Axle:** car, skateboard, pizza cutter
4. **Gear:** bicycle gear, hand beater, wind-up toy
5. **Screw:** corkscrew (also contains levers and gears), jar lid, bolt, drill bit

Note: The Ontario Curriculum categorizes simple machines slightly differently, as lever, inclined plane, pulley, wheel and axle (including gear), screw and wedge. Feel free to use the categorization you feel most comfortable with.

Structured Inquiry Activity

Students work in groups (groups of three are ideal).
Each group needs:

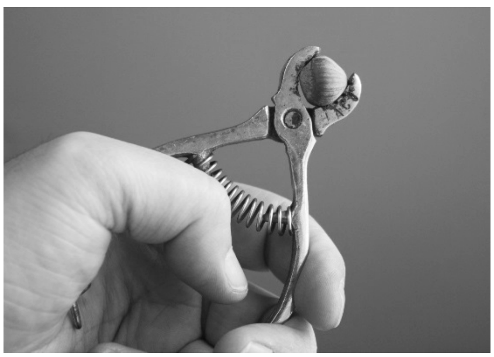
- Long rectangular piece of cardboard
- Ball (lightweight foam balls can be purchased from many dollar stores)
- Three large similar sized books (textbooks are ideal)
- Masking tape
- Whiteboard or worksheet with writing materials

Procedure:

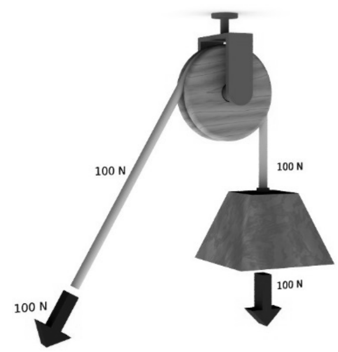
Teaching Basic Concepts

Begin by introducing students to the six types of simple machines. Simple machines make work easier by changing the magnitude (amount) and/or direction of a force. Examples:

- **Changing the magnitude of a force:** It would be difficult to crush a hard-shelled nut with your bare hands. A nutcracker (a lever) makes the work easier by reducing the amount of input force (effort) required. The tradeoff is that the force must be applied over a longer distance.
- **Changing the direction of a force:** A single fixed pulley makes work easier by changing the direction of the force. Instead of working against gravity by lifting a weight up directly, you can work with gravity by pulling down on a rope.



A nutcracker reduces the amount of effort (input force) required on a load (the nut).



This pulley system changes the direction of a force. To lift the weight up, you must pull down.

Introduction to Inclined Planes: What might be another word for an inclined plane? A ramp. Where would students find ramps in or around their school, and who might use them? (Answers include: caregiver with a stroller, a person pushing a grocery cart, a wheelchair user, etc.)

Structured Inquiry Activity

Students will learn more about inclined planes by collecting and analyzing data. Each group gets a long piece of cardboard, three large books, and a small foam ball.

Outlining the experiment: Students work on a long table or on the floor. Start with one book, and tape the top of the cardboard to the edge of the book, creating a small ramp or inclined plane. Next, place the ball at the top of the cardboard ramp, and let it roll down, until it stops. How will students know how far the ball rolls? (By measuring.)

Measure (in centimetres) how far the ball has rolled: start from the end (the bottom) of the inclined plane, and measure to the middle of the ball. Students will keep track of their measurements by recording them on a worksheet or whiteboard (see appendix for example recording sheet). Scientists often repeat the same experiment more than once: students will repeat the ball roll two more times, and record their results for each try.

After three tests with one book, students will repeat the experiment with two books, and finally, with a stack of three books, recording the results for each test. Before beginning the experiment, you may ask your students to predict the results. How will changing the height of the book stack affect the distance that the ball rolls, and why did they make the predictions that they did?

Arriving at a conclusion: After students have completed their experiments, debrief the results in small groups, or as a class. What can they conclude from the distances they have recorded? (The steeper the plane is, the farther the ball travels.) How do they think the steepness of the plane affected the ball's speed as it rolled down? What if they were as tiny as an ant and they had to walk up the inclined plane; what would it be like to walk up a very steep slope? Is there a way that they can create a gentler (less steep) slope that goes all the way up to the top of the three stacked books? (Use masking tape to connect multiple pieces of cardboard together, creating a longer ramp.)

Step 2: Guided Inquiry

Question + ~~Procedure~~ + ~~Solution~~

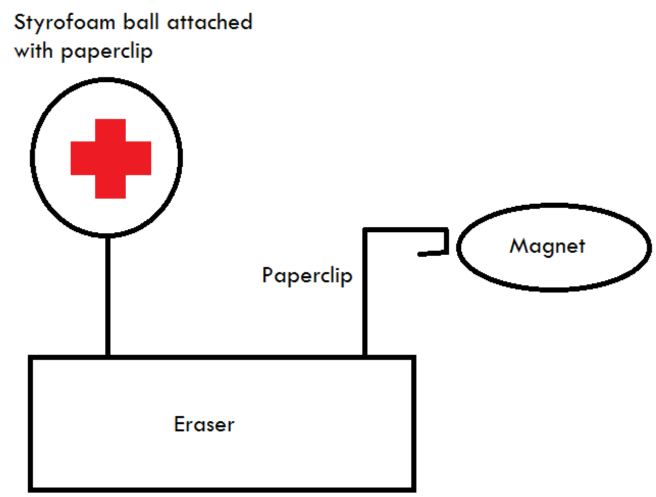
Guided inquiry presents students with a question or a problem to solve. Using experimentation together with their prior knowledge, it will be up to them to determine a procedure and arrive at a solution.

Materials Required:

- Pictures or videos depicting St Bernard rescue dog and Swiss and Italian Alps
  http://blackridgekennel.weebly.com/uploads/2/1/2/4/21244842/9152393_orig.jpg
  https://commons.wikimedia.org/wiki/Matterhorn#/media/File:Panorama_matterhorn.jpg

Students work in groups (groups of three are ideal).
Each group needs:

- Model of "Barry" and his sled (made with an eraser, two paperclips, a Styrofoam ball, and a disc magnet)
  Note: you may have to experiment with finding a disc magnet with just the right amount of strength. It needs to be able to hold the "sled", but not so well that it can be lifted up directly without the use of an inclined plane. We used magnets purchased from a dollar store.
- Many pieces of cardboard, cut into rectangles
- Cardboard rolls (from toilet paper or paper towel), cut lengthwise to form two shallow channels per tube
- Scissors
- Masking tape
- Bench, table, or chair to represent mountains



How to assemble a model of Barry and his sled

Procedure:

Problem #1: Getting Barry up the mountain

Introduce Barry, the St. Bernard dog, and ask students if they have ever seen a dog like this before. Some St. Bernard dogs rescue people from the Swiss and Italian Alps, some very tall and cold mountains in Europe.

Introduce the scenario: The magnet represents Barry the dog, and the eraser is Barry's sled. There is an injured hiker on the other side of the mountain, and Barry needs to bring them some medicine on his sled (show how foam ball sticks to paperclip).

Introduce the problem (what to say): Barry needs to be very careful when pulling the sled, because if he pulls too hard, what happens? (Demonstrate how the magnet sticks to the paperclip on the "sled", but easily detaches on a steep slope.) Barry needs to get up the mountain (a table, desk, or bench), but the mountain is too steep. Luckily, Barry is a very smart dog. What do you think we can build to help Barry get over the mountain? (An inclined plane.) You cannot change the height of the mountain, so what will you need to adjust? (The length of the inclined plane.) Students may use the cardboard to build an inclined plane any way that they want (there is more than one possible solution to the problem). Tape can be used to attach the pieces together, and to attach the inclined plane to the top of the mountain.

Criteria for success: Barry needs to get to the top of the mountain as easily as possible. What does "easy" mean? He has to stay attached to the sled the entire way up (i.e. the magnet must not detach from the paperclip). A gentle slope is required for the solution, but do not tell students this explicitly.

All students in the group must collaborate to find a solution, through discussion, planning, and experimentation.

Problem #2: Getting the medicine down the mountain

Gather students together, and encourage them to discuss their experiments and observations.

Now that Barry has gotten to the top of the mountain with his sled, there is a second problem. The hiker is on the other side of the mountain, and Barry needs to drop the medicine down to the hiker. Ask your students: instead of making a very long inclined plane like before, is there a way we can build one that takes up less space? (Build it on the side of the mountain, using paper rolls this time.)

The medicine is in fragile glass bottles inside the ball, so the ball must travel down the inclined planes as slowly as possible, otherwise the bottles will break. Ask students to discuss among their group members how they should do this (they can adjust the steepness and the number of inclined planes), before they start building.

When groups have a design they are satisfied with, they can time how long it takes for the ball to travel from the top of the mountain to the bottom. The times for each group will be added up, and the goal is to have the longest class time possible.

Step 3: Open Inquiry

~~Question~~ + ~~Procedure~~ + ~~Solution~~
Encourage students to come up with questions about inclined planes that can be answered with experimentation.

Suggested Materials:

Students work in groups (groups of three are ideal).
You may wish to incorporate:

- Small whiteboards and dry erase markers, for students to plan their experiments (in the absence of whiteboards, paper, pencils and erasers work too)
- Many pieces of cardboard, cut into rectangles
- Cardboard rolls (from toilet paper or paper towel): some intact, and some cut into channels
- Foam balls, and other lightweight materials to travel up or down the inclined planes
- Timers
- Scissors
- Masking tape
- Bench, table, or chair
- Students may wish to continue using their "Barry" model (made with an eraser, two paperclips, a Styrofoam ball, and a disc magnet)

Procedure:

Now that students are inclined plane experts, they may begin planning their own experiments, beginning with a question about inclined planes that each group generates on their own. In addition to the question, they should also formulate a prediction (what they think will happen and why), as well as a plan for answering their question.

These Smarter Science resources may help you and your students with the inquiry process:
PEOE (Predict, Explain, Observe, Explain) https://smarterscience.youthscience.ca/peoe-steps
Downloadable posters and worksheets http://smarterscience.youthscience.ca/posters-and-pdfs

STSE Extensions: Relating Science and Technology to Society and the Environment

Escalator vs Stairs

Have you ever walked up an escalator that is out of service? Why does it feel so much harder than walking up the stairs? Develop a hypothesis and plan an investigation.

Ramps and Accessibility

Many buildings use ramps for increased accessibility.

- Who do you think might prefer to use a ramp, instead of stairs?
- Why are ramps often so long? What problems might a person have with a shorter, steeper ramp?
- How can a ramp be modified to accommodate a person with a visual impairment?

Conduct an accessibility investigation at your school, or at another building in your neighbourhood (library, transit station, etc.).

- Use or borrow a stroller or wheelchair, to see what it's like navigating on wheels. Develop a hypothesis before you begin. Are there any things you think will be easy or difficult?
- Record and share your observations.

Follow-up activities:

- Based on your observations, do you have any recommendations to increase accessibility in your school or neighbourhood? Write a letter to your principal or to a community leader, describing your recommendations.
- Design a building (a library, community centre, school or even your own dream mansion) that is accessible to as many people as possible. Draw a floor plan, or construct a diorama of your design.

Friction Ramps

Will it slide? Investigate friction by creating a cardboard ramp. Find a variety of objects made from different materials (you may wish to cover wooden or LEGO blocks in fabric, foil, plastic wrap, paper, etc.), and predict whether they will slide quickly, slowly, or not at all. Test your predictions. Use a stack of books to adjust the steepness of the ramp. Repeat the experiment with a different level of steepness. Have any of your predictions changed?

Extension: Cover the ramp in a different material, and repeat your tests. Compare and contrast your results with your previous investigation.

Simple Machines in Ancient Construction

How did the ancient Egyptians assemble the pyramids? There are a number of different hypotheses, and they all use simple machines in some capacity. Use books or the internet to conduct your own research, and build a model of a device you think would do the job.

Potato Holes: a Simple Machine Inquiry

What's the best way to poke a potato? A simple machine makes it easy! This Science Buddies investigation guides you through a surprising experiment, using different types of wedges.

Research Opportunity: How does a pneumatic nail gun combine a wedge with the power of compressed air?

Appendix

Simple Machines Vocabulary

Effort	Input force applied to a simple machine that produces an output force on the load
Force	Push or a pull by one body on another; these forces can change the speed or direction of an object.
Fulcrum	The pivot about which a lever turns.
Gear	A toothed wheel that engages another toothed mechanism in order to change the speed or direction of transmitted motion.
Inclined Plane	A ramp that reduces the force necessary to lift a weight.
Lever	Rigid bar that pivots about a point (fulcrum) and is used to move or lift a load at one end by applying force to the other end.
Load	A force that resists movement.
Pulley	A simple machine consisting of a wheel with a groove in which a rope can run.
Screw	Inclined plane threaded spirally around a cylinder.
Simple Machine	Device that only requires the application of a single force to work.
Wedge	Any shape that is triangular in cross section and is usable as an inclined plane that can be pushed between two things.

Inclined Plane Experiment

How does the height of the inclined plane affect how far the ball rolls? Measure the length in centimetres (cm).

	Try 1	Try 2	Try 3
1 book			
2 books			
3 books			

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How to construct Barry's sled

Note: You will need to find a magnet with just the right amount of strength. It needs to stick to the paperclip on the "sled", but not so well that the sled can be lifted off the ground without an inclined plane. We used a disc magnet from a dollar store in our experiments. A rare earth magnet (those new magnets with a reflective surface) will likely be too strong.