ACTIVITY 3

HOW TO OUTSMART GRAVITY?

EXPERIMENT OBJECTIVES AND CONTENT

The primary objectives of this activity are to allow students to familiarize themselves with equilibrium of forces and give them a chance to design and build a windmill.

ESSENTIAL KNOWLEDGE

Matter:

- Properties and characteristics of matter in different states (solid, liquid, gas): materials of which an object is made

Forces and motion:

- Effects of gravitational attraction on an object
- Combined effects of several forces on an object

Systems and interaction:

- Other machines (windmill)
- How manufactured objects work

Techniques and instrumentation:

- Manufacturing (cutting, assembling)
- Design and manufacture of structures

Appropriate language:

- Terminology related to an understanding of the material world
- Conventions and types of representations specific to the concept studied: drawings, sketches

SUGGESTED MATERIALS

Scientific equipment:

- Photographs of windmills

Perishable non-scientific materials:

- Water

Household materials:

- Empty thread bobbins
- Empty water bottles
- Cardboard tubes (empty rolls of paper towel)
- Marbles, small stones
- Wooden skewers
- Sir sticks
- Fan

School supplies:

- Pencils, rulers, glue, scissors
- Paper, cardboard
- Modeling clay
- Precision knife

CONTEXT: SITUATIONAL PROBLEM OR RESEARCH QUESTION

At school, your teacher showed a documentary on wind turbines. You were impressed by the height of these huge structures and the size of their rotors. You wonder why wind turbines don't fall forward, even though you, when you're carrying your loaded packsack, sometimes feel wobbly. To resolve this mystery, you decide to build your own miniature windmill and see if you can outsmart gravity too!

SUGGESTED PREPARATORY ACTIVITIES (INTRODUCTION)

The teacher begins a discussion on the effects of gravity and the different forces that act on an object in order for it to reach a point of equilibrium. The teacher could encourage the students to find their own equilibrium points by having them adopt different poses. One leg in the air, arms extended, head pointed down, etc. The students could also try to find the equilibrium point of various objects (e.g., stapler, calculator, brush) by trying to balance them on the end of a finger. The teacher then challenges them to build a solid, well-balanced structure: a windmill. The various materials available to build a windmill could be explored before the experiments are carried out.

REAL WIND TURBINES ARE ANCHORED TO THE GROUND ON CONCRETE PILLARS. FOR THESE EXPERIMENTS, THE WINDMILL IS ONLY A PRETEXT FOR COVERING THE CONCEPT OF EQUILIBRIUM.

INITIAL IDEAS AND HYPOTHESES

Here are a few examples of hypotheses the students might formulate based on their initial ideas:

Example 1
I predict that I can keep a windmill balanced if I add weight on the side opposite the rotor. I predict this because symmetrical objects are often more stable.

Example 2
I predict that I can keep a windmill balanced if I add weight to its base. I predict this because heavy objects are harder for the wind to pick up.

Example 3
I predict that I can keep a windmill balanced if I use light materials such as paper to make the rotors.I predict this because it is easier to support light objects than heavy objects.

WORK PLAN AND EXPERIMENTATION

Here are a few examples of experiments the students can carry out to verify their hypotheses:

Example A
The students pierce two holes opposite one another in the upper part of an empty water bottle, near the neck, and insert a wooden skewer through the holes. The skewer should pass through the centre of the bottle and stick out either side. Over one end of the skewer, they insert a thread bobbin onto which they have glued pieces of cardboard shaped like propeller blades. They can place a small ball of modeling clay on the tip of the skewer to prevent the bobbin from coming off. They then try to keep their windmill balanced by adding weight, in the form of modeling clay, to the other end of the skewer. They test their windmill in front of a fan or outside if it is windy. If the windmill is unbalanced, they add water to the bottle until it stabilizes.

Note: To make the holes, the bottle can be pinched and an incision made with scissors or a precision knife.

RECORD ALL YOUR IDEAS AND OBSERVATIONS IN YOUR EXPERIMENT WORKBOOK.

Example B
The students block one end of a tube by sticking a piece of cardboard to it, which also serves as a base. In the upper part of the tube, about 3 cm from the top, they insert a skewer that passes through the center of the tube from one side to the other. The skewer should stick out a little farther on one side. Over the long end of the skewer, the students place a thread bobbin onto which they have glued pieces of cardboard shaped like propeller blades. They can place a small ball of modeling clay on the tip of the skewer to prevent the bobbin from coming off. They then try to keep their windmill balanced by dropping marbles or small stones into the tube. They can also see what would happen if they make the rotor blades longer. Then they test their windmill in front of a fan. If the windmill is unbalanced, they add marbles or stones into the tube until it stabilizes.

Example C
The students cut a star with long points out of a sheet of paper, then bring the points toward the centre of the star and stick them there to form loops that will serve as propeller blades. They can reinforce the middle by gluing on a small cardboard disc, then they pierce a hole in the middle. To build a tripod, they shape a ball of modeling clay into which they stick three skewers. They solidify the structure by joining the three skewers with strips of paper.

Finally, they put one end of the skewer holding the rotor into the ball of modeling clay, placing a small ball of modeling clay on the tip of the skewer to prevent the rotor from coming off. They test their windmill in front of a fan or outside if it is windy. If the windmill is unbalanced, they add weight in the form of balls of modeling clay stuck to the ends of the skewers that form the base.

EXPERIMENTAL FACTORS
To ensure scientific rigor, the students should evaluate the experimental factors that might influence the experimental results.

- Type of building materials used
- Shape and weight of rotor blades
- Shape and weight of base of windmill
- Location of windmill's centre of gravity
- Strength of wind or fan

DISCUSSION: SUGGESTED INTEGRATION ACTIVITIES (CONSOLIDATION)

The teacher leads a discussion with the class to review the activity's key concepts. The students could also present the particularities of their windmill to the rest of the class and explain how they achieved a state of equilibrium. The teacher can show the students photographs of different types of windmills and wind turbines, allowing them to determine which comes the closest to their own designs. A mini science fair could also be set up at the school to give the students a chance to share their discoveries.

SUGGESTED ACTIVITIES FOR APPLYING KNOWLEDGE (APPLICATION)

The teacher could start the students discussing the magnitude and direction of the various forces exerted on stationary or moving objects. The different mechanisms used by animals to improve their balance when they move could also be discussed, for instance, squirrels and cats, which use their tails to improve their agility. The activity could be complemented by a fieldtrip to a windmill or wind turbine.

SCIENTIFIC CONCEPTUAL CONTENT

Force

A force is applied when you pull or push on an object. Force has magnitude and direction. Forces thus affect how objects move, i.e., they can cause an object to accelerate, slow down or stop. If the force is great enough and the object cannot move, the force can deform or break it up. Force is represented by the unit of measurement called the Newton (symbol: N).

Equilibrium of forces

Equilibrium is the state reached when an object is not, or no longer, in motion. Contrary to what you might believe, there are forces acting on stationary objects, such as gravity and wind pressure. When all of these forces cancel out, it is said that an object has reached a state of equilibrium.

Gravity

Gravity is a force that attracts objects toward the centre of the Earth. All bodies mutually attract each other through a force called gravitation, and the more massive a body, the greater this force. This is why the gravitation exerted by small bodies is too weak to be felt. However, the gravity of massive bodies such as planets is strong enough to attract other bodies toward them. Gravitation is what keeps the Moon in orbit around the Earth. The closer together bodies are, the greater the force of gravitation.

Centre of gravity (balance point)

Centre of gravity, also called centre of mass, is a small and imaginary point on a body on which the force of gravity is exerted. It is as though all of the body's mass were concentrated in this point. The position of a body's centre of gravity depends on its shape. In the case of a regular shape such as a sphere, the centre of gravity is exactly at the centre. When the body is irregularly shaped, the centre of gravity is located near the heaviest part. A hammer's centre of gravity is not very far from the head because the head has more mass than the handle. A person's centre of gravity is located near their navel.

Base and fulcrum

An object's base is the part of it that contacts its support structure. For example, the base of a human standing upright is delimited by the bottoms of the feet. In architecture, the most stable and lightest bases are triangular, such as a camera tripod. For a person or object balancing on a point, such as a tight-rope walker on a wire, one speaks instead of a fulcrum. If a base or fulcrum is placed beneath an object's centre of gravity, it will stay balanced. Thus, the closer an object's centre of gravity is to its base or fulcrum, the more force is required to unbalance it, while the farther away an object's centre of gravity is from its base or fulcrum, the easier it is for it to lose balance.

CULTURAL REFERENCES

Newton's apple

Isaac Newton was one of the greatest thinkers in history. He was born in England in 1642 and died at the age of 85. He showed interest in mechanics from a very young age, and his parents sent him to study in London. His studies were interrupted at the age of 23 because of an outbreak of the Plague. It was around this time that he discovered the laws of motion and gravity. Legend has it that they were inspired after an apple fell on his head while he was standing under an apple tree. These laws revolutionized science because they were valid for everything in the universe, from infinitesimally small bodies such as atoms, to huge bodies such as galaxies. Newton was also interested in other scientific disciplines, including optics, astronomy and mathematics.

Your weight on the Moon

Did you know that a person doesn't weigh the same on the Moon as on Earth? That's because an object's weight depends on the gravity of the body on which it happens to be. Because the Moon's gravity is six times less than that of Earth, you will weigh six times less on the Moon. This is why the astronauts who walked on the Moon were able to literally take giant steps. On the other hand, on Jupiter, you would be much heavier, because gravity on that planet is 2.65 times higher than on Earth. On Earth itself, gravity is not the same everywhere; for example, gravity is a little stronger at the poles because Earth is slightly flattened and the poles are therefore a little closer to the centre of the planet. On the other hand, Earth's gravity is slightly weaker at the equator because it is slightly farther from the centre of the planet.

FOR MORE CULTURAL REFERENCES,
VISIT THE ÉCLAIRS DE SCIENCES WEBSITE:
www.eclairsdesciences.qc.ca

REFERENCES

Ardley, Neil. *Comment ça marche*. Paris: Éditions du Seuil, 1995.

Churchill, Richard E., Louis V. Loeschnig and Muriel Mandell. *Le tour de la science en 365 expériences avec des objets quotidiens*. Cologne: Könemann, 1997.

Cocco, Paolo. *La science: 175 expériences à réaliser*. Issy-les-Moulineaux: Éditions Glénat, 2006.

Firth, Rachel. *Ma première encyclopédie des sciences*. Londres: Usborne Publishing, 2003.

Hewitt, Paul G. *Conceptual Physics.* Ninth edition. San Francisco: Addison Wesley, 2002.

Lasnier, François. *Réussir la formation par compétences*. Montréal: Guérin, 2000.

Serway, Raymond A. *Physique/Mécanique, 2nd edition*. Montréal: Éditions HRW, 1988.

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PROCESS OF ACTIVE DISCOVERY

GENERAL LEARNING PROCESS IN SCIENCE AND TECHNOLOGY (IN ELEMENTARY SCHOOL)

Context related to everyday life

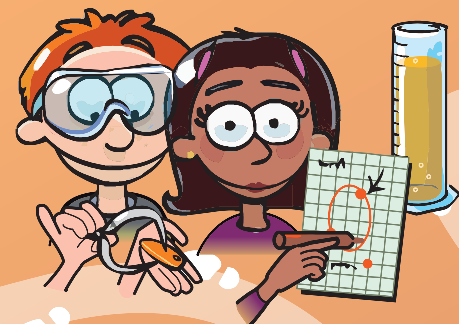
- **Situation problem** or
- **Discovery question** or
- **Need to be fulfilled**
- **Question related to the operation of an object** (how does it work?)

Initial ideas and hypothesis

My initial ideas:
- I share my own ideas.

My hypothesis:
- I predict that...
  I think that because…
- I imagine my prototype.
- I think it works like this…

Planning and carrying out



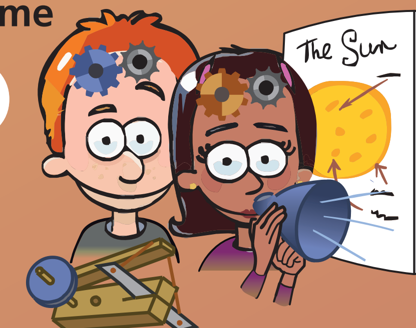
My equipment:
- I observe and handle the equipment.
- How could this equipment be useful to me?
- I choose my equipment and my materials.

Carrying out my process:
- What will the steps be?
- What precautions should I take?

My actions:
- I carry out the steps of my protocol.
- I note or draw what I observe, what I do and what I discover.

My results:
- What is my answer to the problem, question or need?

Outcome



My outcome:
- Do my results confirm my hypothesis or not?
- Are my results similar to those of the other teams?
- Can the other teams' results help me to find answers to my problem, my question or my initial need?
- What could I communicate concerning my discoveries?

New question?

What I learned:
- What do I retain from this activity?
- What could I communicate concerning my results or my discoveries?

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