Laws of Motion with Homemade Helicopters

Companion Lesson to X-STEM All Access Episode "High Flying Role Models"

Grade/ Grade Band: 6-12	**Topic:** Aviation and Newton's Laws of Motion	

Brief Lesson Description: Students meet Helicopter Instructor Pilot Esther Beckett as she discusses the different roles involved in flight school and jobs for helicopter pilots before creating their own: "helicopter" and investigating Newton's Laws of Motion, particularly the 1st law (inertia) and 2nd (F=ma).

Performance Expectation(s):

NGSS 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 the mass of the object.

NGSS HS-PS2-1. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

Specific Learning Outcomes:

1. Design and carry out an investigation
2. Explain the relationship between forces, mass, and acceleration

Narrative / Background Information

Prior Student Knowledge: Students should understand variables; know how to solve multi-step equations, and how to calculate speed and acceleration.

Science & Engineering Practices: Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many pieces of data are needed to support a claim. (MS-PS2-2)
- Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation. (MS-PS2-5) .

Disciplinary Core Ideas: Forces and Motion

- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2)
- Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1)

Crosscutting Concepts: Systems and System Models

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems. (MS-PS2-1,MS-PS2-4)

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2- 1, HS-PS2-5)

Possible Preconceptions/Misconceptions: Many students may believe that forces get things going but don't stop things; an object stops because it runs out of force or energy. During this lesson students learn that objects don't "contain" force, so they can't run out of force but forces (push/pull) interact between two objects.

LESSON PLAN – 5-E Model

ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:

You want students to interact with the X-STEM video featuring AIRBUS Instructor Pilot Esther Beckett.

1. Before viewing, let students know they are going to record notes in real-time using back channeling tools like: Google Classroom's "stream" feature that allows students to chat or Padlet where students create digital post-it notes (for device-free classroom use Post-It Notes).
2. Provide the essential question: **What are some things that Pilot Beckett talks about that make you think outside the box**? encourage students to post notes on anything that makes them think and wonder and anything they notice. Students can respond to a posted comment with constructive dialogue.

(Possible posting topics: STEM careers (engineers, production line, mechanics, and simulation techs), Types of helicopters (Puma, Llama, Squirrel maybe observing name is based on size), Different fields for helicopter pilots (law enforcement, fire fighters, Coast Guard, medical-medic vac, tourism- flying over Grand Canyon).

The goal is to have students engage with the video and for the teacher to collect data regarding student interests and how they are thinking and what makes them wonder.

EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions: In teams of 4, students will create a paper helicopter.

Prior to starting the explore section of this lesson, you will need to gather the following materials per team:

- 2-3 sheets of paper or cardstock
- a meter stick/measuring tape
- scissors
- stopwatch/timer
- paper clips (various sizes)

Instructions for students:

1. Cut the paper into strips of 2 cm by 20 cm
2. Fold the piece of paper in half and then bend the ends to form a T-shape
3. Attach paper clip to the bottom of the T-shape
4. Drop your helicopter from above your head
5. Record how long it takes to hit the ground
6. Then make adjustments to affect the speed at which the blades spin and how quickly it falls to the ground

Allow students 15 mins for exploration.

EXPLAIN: Concepts Explained and Vocabulary Defined:

Explain Newton's Laws of Motion

- Newton's First Law of Motion states that for the motion of an object to change, a force must act upon it. This is a concept generally called **inertia**. Example: if I roll a plastic ball along a table, it slows and eventually comes to a stop. But according to Newton's laws, this is because a force is acting on the plastic ball and, sure enough, there is a frictional force between the table and the ball. That frictional force is in the direction that is opposite the movement of the ball. It's this force which causes the object to slow to a stop.
- Newton's Second Law of Motion defines the relationship between acceleration, force, and mass; **F=ma**. Example**:** a box with a mass of 40 kg sits at rest on a frictionless tile floor. With your foot, you apply a 20 N force in a horizontal direction. What is the acceleration of the box? The object is at rest, so there is no net force except for the force your foot is applying. Friction is eliminated. Also, there's only one direction of force to worry about. So, this problem is very straightforward:

$$\boldsymbol{F} = m * \boldsymbol{a}$$
$$\boldsymbol{F} / m = \boldsymbol{a}$$
$$20\ \text{N} / 40\ \text{kg} = \boldsymbol{a} = 0.5\ \text{m} / \text{s}^2$$

- Newton's Third Law of Motion states that any time a force acts from one object to another, there is an equal force acting back on the original object. If you pull on a rope, therefore, the rope is pulling back on you as well. Another example: you apply a force to a big box of books sitting on a table, the box of books applies an equal force back on you. You notice you need a little more "strength"/ force to overcome the equal force the box is exerting in order to move the box.

Vocabulary:
Newton's First Law of Motion- An object at rest will remain at rest unless acted on by an unbalanced force; an object in motion will continue with constant speed and direction unless acted on by unbalance force (inertia)
Newton's Second Law of Motion- The acceleration of an object depends on the mass of the object and the amount of force applied (F=ma)
Newton's Third Law of Motion-For every action force, there is a reaction force equal in strength and opposite in direction

ELABORATE: Applications and Extensions: Students return to their paper helicopters to 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 the mass of the object, emphasizing the 2nd law of motion. If students have difficulty identifying a question to investigate, try proposing the following: slowing the descent or landing on a bullseye
(Possible investigation questions: does the weight of the blades slow the speed of the helicopter, will increasing the mass of the helicopter impact the speed, how does wind (fan) impact the descent speed of helicopter, can increasing the mass of the helicopter help predict where it will land)
Ensure students clearly identify the independent and dependent variables for the purposes of data collection.

EVALUATE:

Formative Monitoring (Questioning / Discussion): Students complete a write-up of investigation to include: the question they investigated, variables (independent, dependent, and controlled), and instructions for repeating the investigation

Plan of Investigation Rubric

Marks	Descriptor
0	There is no plan of investigation, or it is inappropriate
1	The research question method and scope of the investigation are not clearly stated
2	The research question is clearly stated The method and scope of the investigation are outlined and related to the research question
3	The research question is clearly stated The method and scope of the investigation are fully developed with clearly labeled variables and closely focused on the research question.

Summative Assessment (Quiz / Project / Report): Students write a report analyzing the investigation which includes data collected, summary of investigation, and explains the laws of motion proved

Elaborate Further / Reflect: Enrichment: Students make modifications to their helicopters and attempt to have it land on a specific stop.

SOCIAL EMOTIONAL LEARNING ACTIVITY

SELF AWARENESS and **SOCIAL AWARENESS**

In the X-STEM All Access Video featuring Esther Beckett, Ms. Beckett's key takeaway is building and maintaining relationships. Students will engage in a team building activity entitled, *Flying to New Heights* by Leigh Ann Rodgers of Better Teams designed to get students reflecting on how they work with others.
Inform students there are Four Forces of Flight: lift, weight, drag, and thrust. For this activity think of the terms like this:

- **Lift** (Inspiration) – Things that uplift the team such as connection, humor, giving and/or receiving appreciation.
- **Weight** (Burdens) – Tasks that weigh the team down. Tasks the team resents because they feel obligated to do them but gain little or no happiness or satisfaction from the process. Deadlines that are impossible to meet. Lack of adequate resources or information.
- **Drag** (Annoyances) – Assignments that slow the team's progress. Things that frustrate, annoy or are boring. Needless bureaucracy or cumbersome rules.
- **Thrust** (Energy) – Things that propel the team, provide urgency and momentum. Actions that support, growth and development, and encourage engagement and fulfillment.

Students create a four-square chart, in each square write one of the forces of flight. Then ask students to list things that lift up/ inspired the team as they worked on the helicopter investigation and record in the square labeled LIFT. Repeat the list making for what weight/burdens, drag/annoyances, and thrust/energy. Students then discuss in their groups and identify 2-3 behaviors the team could focus on to help them fly to new heights. Then share out in the whole group with specific actions and ways they want to be held accountable for achieving them.
The goal of the activity is for students to reflect on how well they work in teams and how they can improve. This activity also builds relationships among students.

INTERDISCIPLINARY CONNECTIONS/IDEAS

Math- As students identify and manipulate variables and collect data they are work with the following:
7.EE.B.3 Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form, using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. (MS-PS2-1),(MS-PS2-2)

7.EE.B.4 Use variables to represent quantities in a real-world or mathematical problem and construct simple equations and inequalities to solve problems by reasoning about the quantities. (MS-PS2-1),(MS-PS2-2)

Materials Required for This Lesson/Activity

Quantity	Description
2-3 sheets per team	Sheets of paper or cardstock
1 pair per team	scissors
1 per team	Meterstick/ measuring tape
1 per team	Stopwatch/ timer
	Paper clips (various sizes)

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