Physics of Ship Building

Grade Band: Middle School and High School	**Topic:** Physical Science, Engineering
Brief Lesson Description: Students design boats to explore Newton's Laws and momentum through hands-on learning.	

Performance Expectation(s):

MS-PS2-1: Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.

HS-PS2-2: Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.

Specific Learning Outcomes:

Students will….

-Apply Newton's third law of motion by designing, constructing, and iterating a boat that effectively utilizes the principle of action/reaction forces.

-Analyze how their boat design influences its interaction with water and other boats during collisions

-Define and calculate momentum using the formula p=mv where p = momentum, m = mass and v = velocity

-Apply understanding of momentum to real-world scenarios by measuring the momentum of their boats before and after collisions.

-Engage in the engineering design process to improve the design of their boat using scientific principles.

Narrative / Background Information

For the "Boat Building Physics" lesson, students should possess foundational knowledge of motion, including concepts such as speed, velocity, and acceleration, as well as an understanding of Newton's Laws of Motion, particularly the First Law (inertia), Second Law (force, mass, and acceleration), and Third Law (action-reaction). They should be familiar with momentum as the product of mass and velocity, along with the principle of conservation of momentum in isolated systems. Additionally, students need a basic understanding of the engineering design process, including problem definition, brainstorming, prototyping, testing, and refining designs, as well as hands-on building skills using materials like cardboard and tape. Lastly, they should be comfortable with basic mathematical calculations relevant to mass, velocity, and momentum, as well as scientific inquiry skills for formulating hypotheses, collecting data, and analyzing results during their boat-building experience.

Science & Engineering Practices:	**Disciplinary Core Ideas:**	**Crosscutting Concepts:**
Constructing Explanations and Designing Solutions Apply scientific ideas or principles to design an object, tool, process, or system. **Using Mathematics and Computational Thinking:** Use mathematical representations of phenomena to describe explanations. (HS-PS2-2)	**PS2.A: Forces and Motion** For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (MS-PS2-1) Momentum is defined for a particular frame of reference; it is the mass times the velocity of an object. In any system, total momentum is always conserved. (HS-PS2-2) If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (HS-PS2-2)	**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) When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-2) **Connections to Engineering, Technology and Applications of Science** **Influence of Science, Engineering and Technology on Society and the Natural World** The use of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences such as factors as climate, natural resources, and economic conditions (MS-PS2-1)

Possible Preconceptions/Misconceptions:

1. Students may think that when a ship pushes water backward, the water only moves backward, not realizing that the ship moves forward because of the equal and opposite force applied by the water.
2. Some students may believe that momentum is lost during a collision, not understanding that while momentum is transferred between objects, the total momentum of a closed system is conserved.
3. Students might think that a continuous force is needed for an object (like a ship) to keep moving, rather than recognizing that once a ship is in motion, it will continue moving unless acted on by an external force, such as friction or drag.
4. Students may assume that a heavier ship will move faster because it seems more powerful, overlooking the fact that increased mass requires more force to achieve the same acceleration.
5. Some students might confuse stability with buoyancy, thinking that a floating ship is automatically stable, without considering factors like weight distribution and hull design that affect how easily a ship tips or capsizes.
6. Students may think that a larger propulsion force (e.g., stronger engines) guarantees faster movement without considering the effects of drag, water resistance, and the mass of the ship.

LESSON PLAN – 5-E Model

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

Start the Lesson by showing the students the video "Evolution of Sea Travel." As they watch the video, have students record their notices and wonderings about how ships have changed over time. After the video, students discuss their notices and wonderings as a class.

Then discuss the following questions as a class:
"How do you think the design (including the size and shape) of a ship affects its movement and stability in the water?"
"What forces do you think are involved when a ship moves, stops or collides with another object?"
Explain to students that in this lesson, they will learn about the physics of shipbuilding and how science results in the amazing ships that travel our seas to defend our country, import products, and allow tourists to see the world.

EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:

Students will complete a group activity to explore how boats collide. Their task will be to design a boat that can hold the most possible weight while floating. They will then test their boats in a water-filled container to observe how they perform.

Divide students into small groups and provide them with a copy of the handout:
Student Handout

Provide each group with the suggested supplies to construct their own boat models.

After completing the activity, discuss the following as a class:

1. ***Observations of Motion and Collisions: Based on your observations during the boat collisions, how did the size and shape of each boat influence its motion and the outcome of the collisions? Can you relate these observations back to Newton's Third Law of Motion and the concept of action-reaction forces?***
2. ***Analysis of Momentum: After analyzing the velocity data collected from your boats, how did the initial and final velocities compare before and after the collisions? What conclusions can you draw about the conservation of momentum in your boat system? How does this relate to the principle that the total momentum of a system remains constant when no external forces are acting upon it?***
3. ***Engineering Improvements: Reflecting on your boat designs and the data collected, what changes or improvements would you make to enhance your boat's performance? How would these changes help maximize weight capacity, improve stability, or optimize speed? Discuss how your understanding of physics influenced these design decisions.***

EXPLAIN:

Use the "Newton's Third Law and Momentum in Boat Collisions" presentation to teach students the related physics concepts of Newton's Third Law and Momentum. As students listen, they should take notes on the topics. Following the direct instruction, students should work in pairs to complete the Practice Problems.

ELABORATE: Applications and Extensions:

Students will redesign and retest their boat designs to improve their performance using the science principles of Newton's 3rd Law and Momentum.

Divide students into small groups and provide them with a copy of the handout and building materials suggested in handout:
Student Handout

EVALUATE:

Formative Monitoring (Questioning / Discussion):

Formative Assessment questions throughout the lesson (found in bold, and italics) can be used to check student understanding throughout the lesson. Additionally, you may look at their handouts in the explore and elaborate sections and the practice problems in the explain section.

Summative Assessment (Quiz / Project / Report):

Possible Summative Assessments include

- Group presentations on boat designs and momentum calculations.
- A quiz on Newton's Third Law and momentum conservation principles.
- A reflective essay on what they learned about the physics of motion through their boat-building experience.

Elaborate Further / Reflect: Enrichment:

Students may see the real-world effects of boat collisions by:

-Watching the Nova Video "Why Ships Crash: Inside the Crash that shut down the global economy"

-Reading and discussing the article: "POV: Was the Francis Scott Key Bridge Collapse Avoidable?"

SOCIAL-EMOTIONAL LEARNING ACTIVITY

CASEL Competency Addressed: Self-Awareness and Responsible Decision-making

Ask students, "**When did you receive feedback or look at data about something you did—maybe a test score or sports stats? How did it make you feel?"**

Relate student answers to the idea that data and feedback affect our emotions, self-perception, and motivation. Explain that today's lesson will focus on how to use data to improve skills and reflect on emotional reactions and decision-making processes.

Display or hand out a simple performance data set (this can be related to a previous class project, individual test scores, or a fictional sports statistic). Have students work in pairs to analyze the data. Example questions: ***What does the data tell you? Where are the strengths and areas of improvement?***

After reviewing the data, lead students through a brief self-reflection. Ask: ***"How would you feel if this data were about your performance? Would you feel proud, discouraged, or motivated?"***

Discuss how emotions can influence our response to feedback, and how self-awareness can help us turn feedback into growth opportunities.

Transition into a goal-setting exercise:

Ask students to write down one short-term goal based on the data that would improve their performance. Encourage them to connect the goal to both data (facts) and emotions (feelings of growth and progress).

Example: "I will spend 10 extra minutes reviewing my mistakes in math to improve by 5 points on my next quiz because I want to feel more confident."

Have volunteers share their goals with the class or in small groups. Encourage students to discuss how understanding the data and their emotions helped them set these goals.

Discuss: ***"Why is it important to be both aware of how we feel and what the data shows when we try to improve performance?"***

Emphasize that using both emotional awareness and data makes goal-setting more effective and helps sustain motivation.

Summarize key points:

Data helps us improve, but our emotional response to feedback is just as important.

Understanding how we feel when we receive feedback can help us make better decisions and stay motivated.

Ask students to journal or reflect on how they plan to use feedback (data) in their personal growth (academic, athletic, or personal).

INTERDISCIPLINARY CONNECTIONS/IDEAS

Algebra: Students can use the lesson "(Pollution) Free Shipping" from Great Lakes Now to create a mathematical model to determine how the environmental impact of shipping can be decreased using green strategies.

English Language Arts: Students can use close reading strategies to compare texts related to sailing using the "Sailing:From a Poet's Perspective" Lesson Plan from California Educators Together

Chemistry: Students will practice dimensional analysis using the lesson "Dimensional Analysis of Steamships" from the Steamship Historical Society of America

Materials Required for This Lesson/Activity	
Quantity	**Description**
1 box per group	Cardboard
1 box per class	Straws
1 Roll per group	Tape
1 Pair per group	Scissors
1 Set per group	Weights (Washers, coins, etc.)
1 per class	Water Filled Container (A Kiddie Pool is suggested)
1 per group	Ruler
1 per student	Pencil and Handout Copies

Lesson Created by Jess Noffsinger
For questions please contact
info@usasciencefestival.org