SEAKEEPERS DIGITAL LESSON PLANS
EDUCATIONAL OUTREACH PROGRAM

THE INTERNATIONAL SEAKEEPERS SOCIETY

LESSON 16:

BLUE PRINTS

FOR A BETTER OCEAN

SeaKeepers Digital Lesson Plans
Lesson 16: Blueprints for a Better Ocean

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Activity: Blueprints for a Better Ocean: Designing the Ultimate Marine Vessel

Objective: To explore how different marine vessel features affect performance and sustainability in different ocean environments and apply that knowledge to design and engineer a vessel with a specific purpose - maximizing speed, improving fuel efficiency, or minimizing ecological disturbance.

Grade Level: 7-12+

Estimated Time: 1.5hr

National (US) Next Generation Science Standards Met:
- MS-ETS1 Engineering Design: 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 Engineering Design: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- HS-ETS1-3 Engineering Design: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
- MS-ESS3-3 Earth and Human Activity: Apply scientific principles to design a method for monitoring and minimizing human impacts on the environment.
- HS-ESS3-4 Earth and Human Activity: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

Required Materials: Paper and pencil or electronic note taking or drawing program, as desired.

Lesson Breakdown:
1. Introduction and review of lesson vocabulary (15 mins)
2. Large group activity - evaluating vessel design and discussion (20-25 mins)
3. Small group activity - designing the perfect vessel (15-20 mins)

4. Small group presentations of vessel designs (10-15 mins)
5. Large group discussion and wrap up (15 mins)

Lesson Vocabulary:

- **Hull**: The main body of a ship or other vessel, including the bottom, sides, and deck but not the masts, superstructure, rigging, engines, and other fittings.
- **Inboard motor:** A vessel's engine housed inside its hull.
- **Outboard motor:** An engine with propeller integrally attached for mounting at the stern of a small vessel.
- **Bow:** The forward part of the hull of a vessel, the point that is usually the most forward when the vessel is underway.
- **Stern:** The back or aft-most part of the vessel. Opposite of the bow.
- **Aft:** The rear of a ship, at the direction of a ship’s stern.
- **Starboard:** To the right-hand side of the vessel when facing the bow.
- **Port:** To the left-hand side of the vessel when facing the bow.
- **Transom:** A flat or slightly curved surface forming the stern of the vessel.
- **Deck:** A permanent covering over a compartment or a hull of a ship.
- **Bridge:** The area or platform on a vessel from which it is commanded. Houses essential navigation and control equipment necessary for the safe operation of the vessel. Often referred to as the cockpit on smaller vessels.
- **Helm:** The part of the vessel used for steering.
- **Galley:** The kitchen of a ship or airplane.
- **Cabin:** A compartment below deck on a vessel used for living accommodations.
- **Bilge:** The lowest inner part, or bottom point, on a vessel, designed to collect excess water and be pumped out to prevent water accumulation.
- **Waterline:** The point on the hull of a vessel that corresponds with the water’s surface when the ship is afloat on an even keel under specified conditions of loading.
- **Draft:** The distance between the waterline and the deepest point of the vessel.
- **Stem:** The most forward part of a vessel’s bow, an extension of the keel itself. Most often found on wooden-hulled vessels.
- **Keel:** The main structural member and backbone of a vessel, running longitudinally along the center of the bottom of the hull from stem to stern.
- **Rudder:** An underwater blade that is positioned at the stern of a vessel and controlled by its helm. When turned, it causes the vessel’s bow to turn in the same direction.
- **Beam:** The width of a vessel, measured at its widest point.
- **Displacement:** The weight of water that a vessel pushes aside when it is floating, AKA the loaded weight of the vessel when fuel tanks are full and all stores are aboard.
- **Mast:** A pole that rises vertically from a ship to support the sails.

- **Rigging:** The sails, masts, booms, yards, stays, and lines of a sailing vessel. AKA the cordage only.
- **Main sail:** The most important sail, or sheet of material attached to a mast, to catch the wind and make the vessel move, which is placed on the mainmast.
- **Jib sail:** A sail at the front of the vessel.
- **Salon:** The largest enclosed, common area of a vessel, usually yachts.
- **Head:** The bathroom of a vessel, typically in the bow of the vessel.
- **Bulkhead:** Vertical partition walls which subdivide the vessel's interior into watertight compartments.

Lesson Introduction/Overview:

Marine vessels—from small fishing boats to massive cargo ships—play a crucial role in global trade, transportation, and ocean exploration. However, their design choices can have significant environmental consequences such as affecting fuel consumption, carbon emissions, underwater noise pollution, and even habitat destruction, amongst others. The way a vessel is built—from its hull shape to its propulsion system—can help to determine how efficiently it moves through water and how much of an impact it has on marine ecosystems globally.

For example, hull design plays a critical role in reducing drag and improving fuel efficiency for marine vessels of all types. A streamlined hull, like that of a catamaran, reduces resistance in the water, allowing vessels to travel faster with less energy expended. In contrast, large cargo ships with deep displacement hulls are designed for stability and capacity but consume more fuel to cover a similar distance. Naval architects are constantly refining these designs and incorporating new materials and technologies such as hydrofoils or air lubrication systems to reduce friction and increase efficiency.

Propulsion systems are another key factor. Traditional diesel engines release greenhouse gases and contribute to ocean pollution, but newer alternatives—such as electric motors, hybrid systems, and wind-assisted propulsion—offer more sustainable options. Some modern vessels are even equipped with solar panels, harness wind power using sails or turbines, and can even utilize hydrogen as a fuel source, significantly reducing their environmental footprint. Understanding these advancements helps us move toward cleaner, more sustainable marine transportation that supports marine exploration and protection worldwide.

Beyond fuel efficiency, vessel noise and wake also affect marine life. High-speed vessels with powerful engines create loud underwater noise that can disrupt marine mammals like whales and dolphins, interfering with their communication and navigation. This type of noise is referred to widely as noise pollution. With modern technology, engineers are designing quieter propulsion systems and sound-dampening hulls to minimize this impact. Similarly, large wakes from fast-moving vessels can cause shoreline erosion and disturb delicate ecosystems like coral reefs and seagrass beds. By optimizing hull shapes and controlling speed in sensitive areas using no-wake zones and other local regulations, vessels can reduce their environmental footprint with little to no additional effort or financial input.

By understanding how engineering principles influence vessel efficiency, mobility, and environmental impact, we can develop smarter, more sustainable vessels that reduce harm to marine ecosystems. As future scientists, engineers, and environmental advocates, you have the power to innovate solutions that balance human needs with ocean conservation goals. Through this lesson, you'll explore how different vessel features affect performance and sustainability, then apply your knowledge to design a vessel with a specific purpose—whether that's maximizing speed, improving fuel efficiency, or minimizing ecological disturbance. The ocean's health depends on smarter designs, and your ideas could help shape the future of marine technology!

Instructions:

Part 1: Evaluating Vessel Design (larger group activity)

Featured in this lesson are four different marine vessels created for different purposes, thus each host different functional and aesthetic designs. Review the photos and information provided for each vessel and then, as one large group or in smaller groups assigned to each vessel, answer questions 1-8 below to evaluate the designs used in each and what you believe their intended purpose may be. *Share your answers/thoughts in one large group as necessary before moving to Part 2.*

Vessel 1: “Skyboat 1” - 2018 Ocean Craft Marine Amphibious 9.8M AES




Key Features:

- Length overall (LOA): 32’
- Beam: 10’05”
- Draft: 1’08”
- Displacement: 7,077lbs
- Hull construction: Molded fiberglass, deep V-shape, black antifouling paint
- Deck surface: Inflatable pontoons, fiberglass construction
- Navigation: VHF marine radio, magnetic compass, 2 Garmin chart plotters/sounders/radars

- Electrical: Four 12-volt batteries in aft engine compartment, two 12-volt batteries in the forward deck locker, two 30 Amp inlets, two marine grade 30-Amp shore power cords
- Propulsion: Two 400 horsepower (HP) Mercury gasoline outboard engines, racing series, fully amphibious
- Steering: Hydraulic wheel
- Fuel: Aluminum 115 gallons
- Fresh water: 30 gallons with a 12-volt DC potable water pump
- Holding tank: 6.5 gallons black water
- Cover type: Bimini top

Vessel 2: "Stone Witch" - 2006 Dunn Boatworks Otter 50 Steel Hulled Cutter S/V







Key Features:

- Length overall (LOA): 50'
- Beam: 14'

- Draft: 6’
- Overhead clearance: 62’
- Displacement: 50,000lbs
- Hull construction: Steel plate, full displacement hull, full integrated keel and keel hung rudder, ablative antifouling paint
- Deck surface: Steel with non-skid painted surface
- Navigation: VHF marine radio, magnetic compass, Garmin chart plotter/sounder, Furuno radar, Alpine stereo
- Electrical: One 125-volt, 30-Amp AC inlet, 12-volt DC power
- Propulsion: Sail and auxiliary Perkins Diesel (85 HP)
- Steering: Chain-driven stainless steel wheel
- Fuel: 120 gallons
- Fresh water: 200 gallons, 6-gallon hot water tank
- Holding tank: 100 gallons black water, 50 gallons grey water
- Sail type: One main sail, one staysail, one jib, cutter rigged (single mast)

Vessel 3: “Triple Crown” - 1987 Magnum 70 M/Y

Key Features:

- Length overall (LOA): 70’
- Beam: 17’
- Draft: 4’05”
- Hull construction: Fiberglass and Kevlar
- Deck surface: Fiberglass and Kevlar
- Navigation: VHF marine radio, Furuno NavNet chart plotter/sounder/radar
- Electrical: Six 12-volt batteries, eight GFCI outlets
- Propulsion: Two 2000 HP CRM diesel inboard engines
- Steering: Hydraulic wheel
- Fuel: 1200 gallon diesel
- Fresh water: 250 gallons, 20-gallon stainless steel hot water tank
- Holding tank: 200 gallons black water

Vessel 4: "Bella" - 1965 Riva Tritone Hull #245

Key Features:

- Length overall (LOA): 26'04"
- Beam: 8'07"
- Draft: 1'07"
- Displacement: 5,842lbs
- Hull construction: Mahogany laminated plank, antifouling paint
- Transom type: Finely finished, barrel shaped

- Deck surface: Finely finished wood work
- Navigation: None
- Electrical: 12-volt batteries with marine grade DC wiring, 120-volt/30 Amp AC inlet
- Propulsion: Two 185 HP CHRIS CRAFT gasoline inboard engines
- Steering: Wheel steering
- Fuel: 132 gallons
- Fresh water: None
- Holding tank: None

Review Questions:

1. **Hull Shape & Efficiency:**
    - How would the shape of the vessel's hull impact its speed, fuel efficiency, and ability to navigate different marine environments?
    - Why might a deep V-shaped hull be better suited for offshore exploration and transport, while a flat-bottom hull is more useful in nearshore conditions?
2. **Size & Weight Considerations:**
    - How would the size and weight of the vessel affect its fuel consumption and maneuverability?
    - What are the trade-offs between a large cargo ship carrying more goods versus a smaller vessel that uses less fuel?
3. **Propulsion & Fuel Type:**
    - How does your vessel's propulsion system (diesel engines, electric motors, wind power, hybrid systems) impact the environment?
    - How do vessels benefit from alternative energy sources like wind, solar, hydrogen power, or other types of renewable energy?
4. **Materials & Construction:**
    - What materials appear to be commonly used in vessel construction, and how do you think they affect durability, weight, and environmental impact of your vessel?
    - How do modern shipbuilding materials help reduce drag and improve efficiency compared to traditional building materials? Are traditional materials used at all in newer vessels?
5. **Fuel Efficiency & Emissions:**
    - How do the vessel design choices used in your vessel potentially contribute to greenhouse gas emissions and different types of ocean pollution?
    - In general, what design features help reduce fuel consumption and environmental impact?
6. **Wave & Wake Impact:**

- How does your vessel's hull shape and speed affect the size of waves it might create?
- What are the consequences of large wakes in shallow water ecosystems like seagrass beds or coral reefs? Can your vessel navigate these types of ecosystems without damaging them?

7. **Noise Pollution & Wildlife Disruption:**
    - How do different propulsion systems impact marine life through underwater noise pollution?
    - What design choices can help reduce noise impacts on marine mammals like whales and dolphins? Does your vessel utilize any of these types of designs?
8. **Biofouling & Invasive Species:**
    - How do vessels unintentionally transport invasive species, and what hull features or coatings can help mitigate this problem?
    - What are some types of antifouling methods common for modern vessels, and what are the environmental concerns related to them? Are their tradeoffs in performance vs. environmental impact?
    - Are there any concerns with the systems or antifouling protections that appear to be featured on your vessel?

Review Questions Potential Answers:

1. **Hull Shape & Efficiency:**
    - Narrower, deeper hull shapes known as displacement hulls like a deep V or a rounded bottom are best for fuel efficiency and stability in rough seas, ideal for long distance travel. Wider hull shapes known as planing hulls like those on a catamaran or pontoon are best for fuel efficiency at high speeds, especially on calm waters where the vessel can get on plane easily.
    - See above.
2. **Size & Weight Considerations:**
    - Larger, heavier vessels are less maneuverable and require more fuel than smaller, lighter vessels.
    - At a certain point it will be more efficient to use larger, heavier vessels to transport goods in less trips than using smaller vessels for more trips based on the cost of travel vs. the weight of goods.
3. **Propulsion & Fuel Type:**
    - Diesel and gas vessels produce greenhouse gas emissions that can contribute to global warming. Depending on the type of electric or hybrid engine, they can also produce greenhouse gases as a secondary product, but typically in significantly lower concentrations as compared to traditional diesel or gas engines.

- By utilizing alternative sources of energy like that from solar, wind, waves, currents, etc., you can increase the fuel efficiency of the vessel, which will decrease operational costs and minimize the impact on the environment through decreased air pollution, noise pollution, and water pollution.

4. **Materials & Construction:**
    - Fiberglass, wood, and steel are the most common in addition to different types of plastics. Fiberglass and steel are meant to improve on the lifetime of wood which tends to rot more quickly in ocean conditions and be susceptible to increased impacts from biofouling. Fiberglass and plastic increase environmental impact as they shed microplastics as the vessel ages and can be incredibly harmful to the local environment if they run aground or become derelict.
    - Fiberglass in particular helps with efficiency as it can be precisely shaped and also can incorporate biofouling technologies as opposed to more traditional wood, and is much lighter than steel used for larger vessels. Steel and wood are still used today, especially for larger vessels like commercial ships or tall ships, but fiberglass continues to be the chosen material for smaller vessels and yachts.
9. **Fuel Efficiency & Emissions:**
    - See answers in questions 3 and 4.
    - See answers in questions 3 and 4.
10. **Wave & Wake Impact:**
    - The more water the hull displaces, the larger wake and waves it will create. Displacement hulls like those with a deep V will create large wakes while vessels with planing hulls like catamarans and pontoons will create much smaller wakes.
    - Large wakes or deep hulls can displace sensitive ecosystems like seagrass beds or coral reefs. Deep hulls can run aground and physically damage ecosystem structure while large waves can displace natural structures or introduce sedimentation which can smother sensitive species like coral and seagrass. Vessels with displacement style hulls can reduce their impacts in shallow areas by remaining in marked channels adequate for their vessel draft and using slow speed in marked zones to reduce impact on sensitive ecosystems and slow species like manatees and turtles.
11. **Noise Pollution & Wildlife Disruption:**
    - Diesel and gas engines tend to produce significantly more noise than electric or hybrid engines and sailing with no engine produces minimal underwater sound. Sonar from depth sounders on larger vessels like cargo ships can also impact marine mammal migration patterns due to interaction with their natural echolocation systems. Unnatural noise of any kind underwater can impact

migration patterns, circadian rhythms, and stress levels of sensitive marine species.
  - Type of sonar can change the level of impact on marine mammals.

12. **Biofouling & Invasive Species:**
    - Invasive species can attach to the hulls of boats or be transported on gear or in ballast water. Some vessels incorporate antifouling paints that emit chemicals that prevent fouling species like molluscs, sponges, algae, etc. from growing on the hull surface and creating drag that reduces vessel efficiency. Depending on where a vessel is traveling, there also tend to be regulations regarding antifouling for different countries or regions like emptying ballast water a certain distance from shore, utilizing specific antifouling chemicals, etc.
    - Antifouling paints are the most common - hard bottom paint which slowly releases biocide from the surface through contact leaching; ablative paints which wear away as the boat moves through the water, leaving a fresh surface of biocide on the surface. Other types of antifouling are less common but one to note is ultrasonic antifouling devices which use sound waves at an ultrasonic frequency that vibrate the hull to prevent growth.
    - Dependent on vessel.

Part 2: Designing the Ultimate Marine Vessel (small group activity)

Based on what you learned and observed from Part 1 of the lesson, break into small groups or work individually and outline a basic design to the best of your ability featuring some or all of the components identified above as necessary with the goal of either:

1. Maximizing speed
2. Maximizing fuel efficiency
3. Reducing environmental impact
4. OR a combination of all three

Feel free to get creative with your engineering concepts and explore combinations of equipment and design that might not be familiar to you or modern industries. You should also consider how your design might be influenced by the type of work the vessel is intended to perform (research, eco-tours, liveaboard, global travel, polar exploration, etc.) and how it might perform in different climates and sea conditions.

For a shorter activity, do not focus too much on how each piece would realistically work together outside of major compatibility issues (ie. using sails on a shipping vessel or something similar).

Optional: For a longer activity or larger project, spend a bit more time focusing and researching how each system might work together and any problems that your design may create.

After each group or individual has completed their designs, they should present them to the class, briefly outlining why they chose the major design elements that were featured in order to achieve their chosen goal(s). Following each presentation, the class should answer the following questions (as applicable to the chosen goals) to evaluate the design:

1. What are the most important design considerations that make this vessel suitable for prioritizing fuel efficiency or speed?
2. What design features does this vessel have that impact its ability to serve its intended purpose (research, eco-tours, liveaboard, global travel, polar exploration, etc.)?
3. What features does this vessel have that minimize its overall impact on the local environment as it travels or remains docked?
4. Are there any additions or changes that could be made to this design that would improve its ability to reach its chosen goal(s) or intended purpose?

Wrap-Up Discussion:

Part 1 of this lesson introduced you briefly to the world of maritime vessels and only a few of the long list of factors that must be considered when designing a vessel or engineering new systems to improve efficiency, sustainability, and reliability when at sea. Part 2 of this lesson allowed you to utilize this introductory knowledge to make decisions regarding your own marine vessel design in order to better understand the decision making processes and trade-offs associated with marine engineering projects, including environmental sustainability.

Following your Part 2 presentations, use the following questions to guide your large group discussion about what you have learned and where you think opportunities for improvement might exist in the marine vessel design and engineering process:

1. What trade-offs do marine engineers and naval architects face when trying to make vessels both highly functional and environmentally friendly?
2. How can improving efficiency benefit both the environment and the industries that rely on marine vessel use for recreation, transportation, etc.?
3. Do you think all marine vessels should be required to use sustainable technologies, or should it be a choice? If so, which technologies do you think should be required and why?
4. What are some emerging technologies or innovations that you think could make marine vessels even more sustainable in the future?

5. In your opinion, how can marine vessels be encouraged to adopt more eco-friendly designs and practices?

For more information on sustainable boating, ocean recreation, and how you can get involved as a citizen scientist, student, business, or vessel operator, visit seakeepers.org.