Exploring Oceans Deep: Nature-Inspired Engineering

Companion Lesson to X-STEM All Access Episode "Putting Brains in AUVs"

Grade Band: 6-12	**Topic:** Biomimicry and Engineering Design

Brief Lesson Description:
Students explore manta ray-inspired AUV design, research, and present their findings to discover the field of biomimicry.

Performance Expectation(s):
HS-ESS3-4: Evaluate or refine a technological solution that reduces the impacts of human activities on natural systems.
MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing human impact on the environment.

Specific Learning Outcomes:

1. Students will be able to identify and explain how specific characteristics of manta rays can be emulated in the design of autonomous underwater vehicles (AUVs).
2. Students will collaborate effectively in groups to research, analyze, and present information on biomimicry and AUV technology, demonstrating their understanding of the subject matter.
3. Students will create a conceptual model of an AUV inspired by manta rays, incorporating features that enhance movement, data collection, and environmental sustainability.

Narrative / Background Information

In this lesson, students will embark on an exciting journey to explore the fascinating world of biomimicry by examining how manta rays can inspire innovative designs in autonomous underwater vehicles (AUVs). The lesson centers on the X-STEM episode "Putting Brains in AUVs" where Northrop Grumman software engineer, Eythan Jenkins, discusses his contributions to the Manta Ray–an unmanned vessel for deep-sea missions. Northrop Grumman developed and tested the Manta Ray prototype as part of the Defense Advanced Research Projects Agency (DARPA) program.

To successfully engage with this lesson, students should have a foundational understanding of basic biological concepts, particularly animal adaptations and ecosystems. They should be familiar with the idea that organisms evolve features that help them survive in their environments. Additionally, students should have some prior knowledge of technology, specifically how devices like AUVs are used in ocean exploration and environmental monitoring. Familiarity with teamwork and presentation skills will also enhance their collaborative research and design efforts throughout the lesson. This background will enable students to critically analyze how the unique characteristics of manta rays can lead to innovative solutions in engineering, paving the way for a deeper appreciation of both nature and technology.

Science & Engineering Practices:	**Disciplinary Core Ideas:**	**Crosscutting Concepts:**
Constructing Explanations and Designing Solutions Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ESS3-4) Apply scientific ideas or principles to design an object, tool, process or system. (MS-ESS3-3)	**ESS3.C: Human Impacts on Earth Systems** Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4) Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. (MS-ESS3-3) Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. (MS-ESS3-3) **ETS1.B: Developing Possible Solutions** When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability, and aesthetics and to consider social, cultural, and environmental impacts. (Secondary to	**Cause and Effect** Relationships can be classified as causal and correlational, and correlation does not necessarily imply causation. (MS-ESS3-3) **Stability and Change** Feedback (negative or positive) can stabilize or destabilize a system (HS-ESS3-4) **Connections to Engineering, Technology, and Applications of Science** **Influence of Science, Engineering, and Technology on Society and the Natural World** Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-ESS3-4) The uses 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 in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region

	HS-ESS3-4)	and over time. (MS-ESS3-3)

Possible Preconceptions/Misconceptions:

1. **Biomimicry is Just Imitation:** Students may believe that biomimicry simply involves copying nature without understanding that it requires thoughtful adaptation and innovation based on biological principles to solve human challenges.
2. **All Animals Function the Same Way:** Students might assume all animals, including manta rays, have similar adaptations. They may not recognize the unique features of manta rays that specifically aid their movement and survival in aquatic environments.
3. **AUVs Are Only for Military Use:** Some students may think that autonomous underwater vehicles are primarily used for military applications, overlooking their significant roles in scientific research, environmental monitoring, and ocean exploration.
4. **Technology and Nature Are Separate:** Students may have the misconception that technology and nature are distinct entities, failing to see the interconnectedness of human innovation with natural systems and the potential for technology to enhance environmental sustainability.

LESSON PLAN – 5-E Model

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

Hook: Show this short video of manta rays swimming gracefully and an AUV in action. Ask students how they think nature inspires technology. Facilitate a discussion about what features of manta rays might be useful for an underwater vehicle (e.g., movement, adaptability, efficiency).

Introduce students to the focus question for the rest of the lesson: ***"How can the unique characteristics of manta rays inspire the design of an autonomous underwater vehicle that effectively explores and monitors ocean environments?"***

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

Divide students into three groups. Assign each of the groups one of the following questions to research:

1. ***How does the body design of a manta ray aid in its movement?***
2. ***What technology is used in AUVs to gather data?***
3. ***How can AUVs help in environmental monitoring?***

Provide each group time to research their question and create a one-slide presentation to share their information with other students.

Regroup students into groups of three. Each new group should have one member for each of the research questions. Have each member of the group present their findings to the other two members. Remind students to focus on how the features of manta rays can be translated into AUV design.

EXPLAIN:

Show the video "Innovation Inspired by Nature" from the Biomimicry Institute.

Explain that when engineers design using biomimicry, three main elements are useful:

EMULATION: The attentive practice of learning from nature's forms and processes to guide human innovation and to create more regenerative design solutions.

ETHICAL FRAMEWORK: A commitment to apply lessons learned from life's systems in a manner that creates conditions conducive to life, and a recognition that we have a responsibility to conserve and protect that which we are learning from.

(RE)CONNECTION: Acknowledgement that humans and our activities are not separate from nature, but are a part of nature, affecting and affected by all other organisms within Earth's interconnected systems. As a practice, reconnecting with nature encourages us to observe and spend time in nature to better understand how life works so that we may more effectively appreciate and emulate biological strategies in our designs.

Show the X-STEM episode " Putting Brains in AUVs". As students watch the video, ask students to consider ***"How the engineers who designed the Manta Ray might have used biomimicry in their work?"***

Possible answers include:

1. Shape and Form
- The Manta Ray UAV has a sleek, wide, and flat body, much like an actual manta ray.
- This hydrodynamic (or in this case, aerodynamic) shape reduces drag, increases lift, and allows for efficient gliding and long-duration

missions, similar to how manta rays glide through water with minimal effort.

2. Movement and Control
- Manta rays use graceful, flapping wing-like movements to move through water.
- Engineers mimicked this by designing control surfaces or flight mechanics that allow the UAV to **maneuver smoothly and efficiently**, potentially using bio-inspired movement strategies.

3. Energy Efficiency
Just as manta rays conserve energy by gliding for long periods, the UAV is designed for long-endurance missions without needing to surface or be refueled often.
- This is crucial for surveillance, ocean monitoring, and stealth operations.

4. Stealth and Camouflage
- The manta ray's natural shape helps it blend into the ocean environment when viewed from below.
- Similarly, the AUVs low-profile design reduces its visibility to radar and other detection systems.

ELABORATE: Applications and Extensions:

Design Challenge:
In their groups of three, students will design their own AUV inspired by manta rays. They should consider:

- Features that help it move efficiently (e.g., wing shape, body structure).
- Sensors and technology for data collection (e.g., cameras, water quality sensors).
- Environmental considerations in their design (e.g., energy sources, minimizing ecological impact).

Model Creation:
Students will create a model or a detailed drawing of their AUV, labeling features and explaining their functions. Provide a variety of model-building materials found locally as well as scissors, tape, glue, and rulers.

EVALUATE:

Formative Monitoring (Questioning / Discussion):
Questions throughout the lesson that are in ***bold, italics*** can be used for formative assessment. Teachers may also review the presentation slides in the explore section of the lesson.

Summative Assessment (Quiz / Project / Report):

Presentation:
Each group will present their AUV design to the class, explaining how it is inspired by manta rays and its potential impact on ocean exploration. Teachers may assess using the rubric provided.

Peer Review:
Students will provide constructive feedback to each group based on the rubric that assesses creativity, scientific understanding, and presentation skills.

Elaborate Further / Reflect: Enrichment:
Students may further their understanding of biomimicry through one of the following extension activities:

1. Participate in the Biomimicry Youth Design Challenge held annually.
2. Complete a research project where students can choose a specific organism and research how its adaptations have inspired technological innovations.
3. Explore more examples of Biomimicry using the Science Trek Collection at PBS Learning Media.

CAREER CONNECTIONS

There is a wide variety of careers students can pursue in the design of vehicles. From designing AUVs to studying the depths of the ocean or the farthest areas of the Amazon, there are many interesting careers for students to learn about. The following activity will provide students with an opportunity to learn about these careers.

Go to https://usasciencefestival.org/resources/ to access the Student Career Resources.

Select the "Land, Air & Sea Vehicles" industry.

Have students browse the careers within your chosen cluster. Select one career that they would like to learn more about. They should then gather the following information using the student graphic organizer or in a class notebook:

- Job description and typical responsibilities
- Education and training required
- Skills and qualities needed
- Average salary
- Work environment and schedule
- Professional Organizations, Educational Programs, and Internship & Apprenticeship Opportunities

Choose a Choice Board Activity and use the information gathered to complete the chosen activity.

Resume for the Future Create a resume as if you are applying for a job in your chosen career 10 years from now. Include education, experience, and skills.	**Work Environment Design** Draw or digitally create an image of the typical work environment for this career. Annotate it with labels explaining the features.	**Career Advertisement** Create a commercial (video or audio) to promote your chosen career to others. Highlight its benefits and opportunities

Provide students an opportunity to share their findings with peers or with you.

SOCIAL EMOTIONAL LEARNING ACTIVITY

CASEL Competency Addressed: Self-Awareness

In the X-STEM Episode "Putting Brains in AUVs", Eythan Jenkins talked about the importance of learning how you learn best. This activity will help your students to do just that!

Begin with a brief discussion about learning styles. Explain that everyone has different ways of learning, and recognizing these differences can help them succeed in school and other areas of life. Introduce the three primary learning styles: visual, auditory, and tactile.

Have students take the "What's Your Learning Style" self-assessment.

After completing the inventory, have students discuss their results in pairs or small groups. Encourage them to share their primary learning style and one example of how it helps them in school or at home. Then, as a class, generate a list of learning strategies corresponding to each learning style on chart paper or a whiteboard.

Provide students with reflection prompts to write about their learning style, such as:

- "How does knowing my learning style help me in my studies?"
- "What strategies can I use to enhance my learning based on my style?"
- "How can I adapt to help classmates with different learning styles?"

Allow students time to write their reflections individually. Invite a few students to share their reflections with the class if they feel comfortable. Conclude the activity by emphasizing the importance of understanding their own learning preferences and being open to different ways of learning from others.

Materials Required for This Lesson/Activity

Quantity	Description
Class Supply	Model Making Materials Suggested materials include: Recyclables, cardboard, foam core, string, pipe cleaners, paint, foam sheets, popsicle sticks, toothpicks, etc.
Class Supply	Scissors, Glue, Tape, and Rulers

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