



MANGROVE CITY

A Middle School Curriculum on Mangrove Ecology and Sustainable Climate Solutions

MANGROVE CITY

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ABOUT THIS CURRICULUM

TARGET GRADES Middle Grades 5-8.

DURATION 1-2 class periods with opportunities for extension.

"Mangrove City" is an accessible and immersive virtual reality experience that integrates seamlessly into classroom learning. This engaging VR module is aligned with the Next Generation Science Standards, providing middle school students with a series of virtual activities that foster a fundamental understanding of the significant role mangroves play in building a sustainable climate future.

This curriculum equips educators with valuable tools, such as a downloadable teacher program for 1-2 class period virtual reality exploration of "Mangrove City" that includes student response forms and an expertly crafted discussion guide. In addition, we have included supplementary lesson plans and activities that extend the connections between Mangrove City and core principles outlined in the Next Generation Science Standards.

We invite you to let "Mangrove City" empower your students with knowledge, inspire their curiosity, and ignite their passion for environmental conservation. Embark on this immersive educational journey, where science, technology, and the wonders of nature converge to shape informed citizens and stewards of tomorrow.

WELCOME TO MANGROVE CITY

DURATION: 1-2 CLASS PERIODS

LESSON OVERVIEW

This immersive virtual reality experience will take students on an exciting journey through "Mangrove City," a futuristic city designed to encompass a vibrant blend of natural and man-made elements and inspired by the resiliency of mangroves. Situated along the coastline, the city uses cutting-edge biomimicry concepts to adapt and thrive in an environment increasingly impacted by climate change.

The journey starts with a comprehensive tutorial on using the VR hardware and software, ensuring all students are fully prepared to navigate the virtual landscape. Next, students will progress through various interactive stations, each offering unique insights into the significance of mangroves in building a sustainable climate future. At each station, there will be a built-in assessment, enabling continuous evaluation of their learning progress.

The experience is crafted to engage students actively. Included in the curriculum is a pre-assessment designed to gauge students' existing knowledge and curiosity about mangroves and their relevance to our climate. A guided discussion will follow the VR experience, encouraging participants to reflect, share insights, and ask questions.

But the journey doesn't end with the VR adventure. After exploring "Mangrove City," students will be excited to participate in the "Mangrove City" Design Challenge. They will apply the principles learned from the VR module and take part in a city design project, where they will envision and create sustainable infrastructure inspired by the lessons taught by mangroves in the virtual world.

By the end of this lesson, our goal is to empower your students with a deeper appreciation for the vital role of mangroves in our environment and inspire them to envision a greener and more sustainable future. Let's dive in together and embark on this educational journey, where nature and technology converge to shape informed and environmentally conscious citizens. ***Are you ready to explore "Mangrove City"?***

INTRODUCTION TO MANGROVE ECOLOGY FOR TEACHERS

Mangrove ecosystems are unique and dynamic environments located in the intertidal zones of tropical and subtropical coastlines. These complex ecosystems, composed of salt-tolerant trees and shrubs, provide a plethora of ecological services and play a pivotal role in bolstering climate resilience.

At the heart of mangrove ecosystems are the mangrove trees. They have evolved adaptations to thrive in saline, oxygen-poor conditions that would be inhospitable to most other plant species. Features such as pneumatophores (aerial roots) that take in air, salt-filtering roots, and propagules (viviparous seeds that can survive sea dispersal), are all adaptations that make mangroves a remarkable feature of the tropical coasts.

One of the key ecological services offered by mangrove ecosystems is carbon sequestration. Mangrove forests are highly efficient at absorbing and storing carbon dioxide from the atmosphere, trapping it in their leaves, stems, extensive root systems, and surrounding soil. This process aids in mitigating climate change by reducing the amount of greenhouse gasses in the atmosphere. In fact, even though mangroves only account for about 0.1% of the Earth's tropical forest area, they contribute significantly to total carbon sequestration.

Mangroves are also crucial in protecting coastal communities from extreme weather events that are becoming more common and stronger with climate change. The dense network of roots and branches act as natural buffers against storm surges, tsunamis, and hurricanes, absorbing the impact of the water and wind and reducing the damage on shore.

Moreover, mangrove ecosystems help maintain water quality by filtering pollutants and trapping sediments from the water, preventing them from damaging coral reefs and seagrass beds. They also provide a habitat for a variety of marine and terrestrial species, serving as a nursery ground for many fish species and supporting rich biodiversity.

Despite their significant ecological importance, mangrove ecosystems are under threat due to factors such as deforestation, pollution, overfishing, and rising sea levels. Protecting and restoring these ecosystems is an essential step toward climate resilience and sustainability.

In the face of climate change, the importance of mangrove ecosystems is more critical than ever. Their intrinsic link to coastal protection, carbon sequestration, and biodiversity, make them invaluable in our efforts to adapt to and mitigate the impacts of a changing climate. As a result, mangroves can be seen as a natural climate solution and their conservation needs to be prioritized in climate action strategies globally.

OBJECTIVES

By the end of the "Mangrove City" experience, students will be able to:

- Identify the key components and features of a mangrove ecosystem, including some mangrove species, their adaptations, and the unique ecological niches they occupy.
- Describe the ecological services provided by mangroves, such as water filtration, coastal protection, and supporting biodiversity in coastal areas.
- Engage in guided discussions to reflect on the significance of mangroves in shaping a sustainable climate future, sharing insights, and discussing potential solutions to environmental challenges.
- Utilize critical thinking skills to evaluate the importance of preserving mangrove habitats and the potential implications of their loss on coastal communities and global ecosystems.
- Apply knowledge gained from the VR experience to design a sustainable city, integrating principles learned from mangrove habitats.

PROCEDURE AT A GLANCE

Step 1: Introduction and Hardware Tutorial

- Show students an image of a mangrove forest. Have students complete the What Do You Know About Mangroves pre-assessment worksheet, using the image as a guide.
- Use the “Welcome to Mangrove City” Slideshow to begin a discussion of mangrove ecosystems and their importance in sustainable climate solutions.
- Introduce the VR experience and provide a basic tutorial on using VR hardware and software, ensuring all students are familiar with navigation and interaction in the virtual world.

Step 2: Exploring “Mangrove City” Stations

- Students will progress through various interactive stations within the VR experience, each focusing on a specific aspect of mangrove ecosystems.
- At each station, students will engage in immersive activities, such as learning about mangrove species, ecological services, carbon sequestration, and the vital relationship between mangrove roots and ocean waves.

Step 3: Built-in Assessments

- As students move through each station, built-in assessments will gauge their understanding and knowledge retention.
- These assessments will provide real-time feedback and help identify areas where students may need additional support or clarification.

Step 5: Reflection and Discussion

- After completing the VR experience, facilitate a guided discussion to reinforce key concepts and the importance of mangroves in climate sustainability.
- Encourage students to reflect on how their understanding of mangrove ecosystems has evolved, and how they can apply this knowledge to contribute to a greener and more sustainable future.

Step 6: Extension: City Design Activity

- Using principles learned from the module, they will envision and create a sustainable city that incorporates eco-friendly elements inspired by mangrove habitats, such as carbon sequestration strategies and eco-friendly infrastructure.

WHAT DO YOU KNOW ABOUT MANGROVES?

STUDENT WORKSHEET

Instructions: Before embarking on the "Mangrove City" VR module, please take a few moments to answer the following questions based on what you already know or wonder about mangrove ecosystems. *Refer to the image provided by your teacher to guide your thinking.*

1. What are mangroves, and where are they typically found? What can you speculate from the picture?
2. Based on what you see in the picture, how do you think mangroves might contribute to the environment and ecosystems?
3. Have you heard or read about any specific benefits or challenges related to mangroves and climate change? If yes, please share your knowledge or any sources that have informed you.
4. What questions or curiosities do you have about mangrove ecosystems and their significance in relation to our climate? Is there anything specific you hope to learn or explore during the "Mangrove City" VR module?

GUIDED DISCUSSION

1. What aspects of the "Mangrove City" VR experience stood out to you the most? How did these elements contribute to your understanding of mangrove ecosystems and their role in shaping a sustainable climate future?
2. Throughout the VR module, you learned about the ecological services provided by mangroves. Which specific services do you find most critical in the context of climate change and environmental conservation? Why?
3. Reflecting on your prior beliefs about climate change, has the "Mangrove City" module influenced or reinforced your views in any way? If so, in what ways?
4. Looking at the bigger picture, how do you see the preservation and conservation of mangrove habitats contributing to a more sustainable global environment? What role can individuals and communities play in supporting these efforts?
5. What new insights or knowledge have you gained about mangroves and their significance in combating climate change? How might this awareness influence your actions or choices in the future?
6. How can the ecological features and functions of mangroves, as explored in "Mangrove City," inspire sustainable design concepts for urban coastal settlements?
7. What questions or topics related to mangroves and climate change do you still have, and how can we further explore or address them in future learning opportunities?

“Mangrove City” Design Challenge

Objective: Students will apply the principles learned from the "Mangrove City" VR module to create a sustainable city design for an urban settlement, incorporating ecological concepts inspired by mangrove ecosystems.

NGSS Standards and Performance Expectations:

Middle School 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-ETS1-1)
- Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. (MS-ETS1-2)
- Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. (MS-ETS1-3)
- Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. (MS-ETS1-4)

Middle School Physical Science

- Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes. (MS-PS1-6)

Middle School Life Science

- Evaluate competing design solutions for maintaining biodiversity and ecosystem services. (MS-LS2-5)

Middle School Earth and Space Science

- Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. (MS-ESS3-3)

Materials:

1. Drawing paper or digital design software (if available)
2. Markers, colored pencils, or other drawing materials
3. Presentation tools (e.g., projector, screen)
4. Sustainable city design resources (optional)
5. Assessment rubric for the urban design challenge

Procedure at a Glance:

1. Introduction (15 minutes):

- Recap the key concepts from the "Mangrove City" VR module, emphasizing the ecological significance of mangroves in combating climate change and preserving coastal environments.
- Explain the objective of the urban design challenge: Students will create a sustainable city design incorporating principles learned from mangrove ecosystems.

2. Exploring Sustainable Design Concepts (30 minutes):

- Present examples of sustainable design features (see Introduction to Green Design for Teachers), highlighting elements like green spaces, eco-friendly architecture, renewable energy sources, and smart infrastructure.
- Discuss how these concepts align with the ecological services provided by mangroves, emphasizing features such as water filtration and protection against coastal erosion.

3. Design Brainstorming (25 minutes):

- Divide students into small groups and provide them with drawing materials.
- In their groups, encourage students to brainstorm ideas for their sustainable city designs, incorporating elements inspired by mangrove principles and the examples presented.
- Students should consider the city's layout, transportation, green spaces, water management, and other eco-friendly features.

4. Group Presentations (20 minutes):

- Each group will present their initial design concepts to the class.
- Encourage students to explain how their design choices reflect the ecological importance of mangroves and contribute to a more sustainable urban environment.

5. Refining the Designs (40 minutes):

- After the group presentations, allow time for students to receive feedback from their peers and make improvements to their city designs.
- Provide access to additional resources or information on sustainable urban design for students to incorporate into their plans.

6. Finalizing the Designs (30 minutes):

- Students will work on finalizing their city designs, ensuring they incorporate both creative and practical elements of sustainable design inspired by mangrove principles.

7. Presentation Prep (15 minutes):

- Each group will prepare a brief presentation to showcase their final sustainable city designs.
- Remind students to highlight the specific ecological benefits of their design choices and how they contribute to climate resilience.

8. Group Presentations (20 minutes):

- Each group will present their completed sustainable city designs to the class.
- Encourage questions and discussions after each presentation, allowing students to engage in constructive feedback and further explore the connections between mangrove-inspired design and sustainability.

Assessment: Evaluate students' participation, engagement, and the quality of their sustainable city designs using a rubric that assesses how well they integrated mangrove-inspired ecological concepts into their urban plans. Provide feedback and encourage students to continue exploring sustainable design concepts beyond the lesson.

INTRODUCTION TO GREEN DESIGN FOR TEACHERS

Green design inspired by nature, often referred to as biomimicry or biophilic design, takes cues from natural processes and organisms to create more sustainable and efficient human systems and structures. This approach allows us to learn from nature's billions of years of trial and error to find sustainable solutions to human challenges. Here are a few examples:

Architecture Inspired by Termites: The Eastgate Centre in Harare, Zimbabwe, has a passive cooling system inspired by termite mounds. Termite mounds maintain a near constant temperature inside, regardless of the outside temperature. The Eastgate Centre uses a similar design to ventilate the building, reducing the building's energy consumption by mimicking this natural temperature control.

Solar Cells Inspired by Leaves: Some solar cells are designed to mimic the way leaves capture sunlight for photosynthesis. These "bionic leaves" use a process similar to photosynthesis to split water molecules into hydrogen and oxygen, creating a source of renewable energy.

Water Collection Inspired by Namib Desert Beetles: The Namib Desert beetle survives in its arid environment by collecting water droplets from morning fogs on its back, where a pattern of hydrophilic (water-attracting) and hydrophobic (water-repelling) areas channels the water directly to the beetle's mouth. This principle has been mimicked in designs for water collection systems in dry regions.

Wind Turbines Inspired by Humpback Whales: The design of wind turbine blades has been inspired by the flippers of humpback whales, which have a series of bumps (tubercles) on the leading edge. This adaptation increases the whale's agility in the water. The biomimetic application of these tubercles on wind turbine blades reduces drag and noise and increases efficiency.

These are just a few examples of how observing and understanding nature can lead to significant advancements in green design, allowing us to create systems and structures that are more efficient, sustainable, and harmonious with the environment.

Check out this resource on nature-inspired design:

<https://doi.org/10.1038/s41427-021-00322-y>

“Mangrove City” Design Challenge

STUDENT WORKSHEET

Instructions: Collaborate with your group and sketch out a preliminary layout of your city design. Answer the questions below as you brainstorm your ideas.

Write down five sustainable design features you wish to include in your city design:

- 1.
- 2.
- 3.
- 4.
- 5.

Explain how each design feature aligns with the ecological services provided by mangroves:

- 1.
- 2.
- 3.
- 4.
- 5.

“Mangrove City” Design Challenge

INITIAL DESIGN CONCEPT PEER REVIEW SHEET

Instructions: Each group will present their initial design concepts to the class. Take notes on feedback and suggestions you receive for your initial design:

Positive Feedback:

Suggestions for Improvement:

Refining Your Design: Based on the feedback received, identify three changes or additions you plan to make to your design:

1.

2.

3.

“Mangrove City” Design Challenge

REFLECTION QUESTIONS

1. How does your city design promote sustainability and resilience to potential climate impacts?

2. What was the most challenging part of incorporating mangrove-inspired principles into your urban design? How did you overcome this challenge?

3. How might this design exercise be applicable in real-world scenarios of urban planning?

"Mangrove City" Design Challenge Rubric

The rubric is intended to provide guidance and assessment for the "Mangrove City" urban design challenge. Teachers may adapt and modify the rubric based on specific learning objectives and classroom needs.

Criteria	On Target	Approaching Target	Below Target
Understanding of Mangrove-Inspired Concepts	Demonstrates a clear and in-depth understanding of how mangrove ecosystems contribute to sustainability and climate resilience.	Shows some understanding of mangrove-inspired principles but may lack depth or clarity in their explanation.	Displays limited knowledge of mangrove-inspired concepts and their relevance to sustainable design.
Integration of Sustainable Elements	Successfully integrates a variety of eco-friendly features inspired by mangroves, including green spaces, renewable energy sources, water management systems, and climate-resilient infrastructure.	Attempts to include some sustainable elements in the urban city design but may lack cohesiveness or overlook important aspects.	Struggles to incorporate significant sustainable elements into the urban city design, resulting in a design that lacks clear environmental consideration.
Presentation and Communication	Delivers a well-organized and engaging presentation, clearly articulating how the city design integrates mangrove-inspired concepts and sustainable elements.	Presents the city design with some organization, but communication may lack coherence or miss essential details.	Struggles to present the urban city design coherently and may have difficulty explaining the incorporation of mangrove-inspired elements and sustainability concepts.

BEYOND MANGROVE CITY

DURATION: MULTIPLE CLASS PERIODS

SUPPLEMENTARY LESSONS

We are excited to introduce a series of supplemental activities that will take your learning adventure beyond "Mangrove City" and into various areas of the middle school science curriculum. These engaging activities, carefully aligned with the Next Generation Science Standards (NGSS), will provide you with deeper insights into the wonders of mangrove ecosystems and extend your students' knowledge across multiple science disciplines.

These supplemental lessons correspond to specific stations in the "Mangrove City" VR experience, and are designed to enhance critical thinking, problem-solving skills, and a deeper appreciation for the natural world. As students embark on this extended learning journey, they will uncover the interconnections between mangroves and various scientific disciplines, making meaningful connections across your middle school science curriculum.

We encourage you to embrace this opportunity to explore, discover, and expand your knowledge beyond "Mangrove City." Together, let's become informed and environmentally conscious citizens, ready to contribute to a greener and more sustainable future. Get ready to dive into the wonders of mangroves and the boundless opportunities for scientific exploration that lie ahead!

Activity 1: Biomimicry Blitz – Unleashing Nature's Solutions for Climate Resilience

In “Mangrove City,” students delved into the unique adaptations of mangrove species and learned how to identify these fascinating trees. They observed their physiological features that allowed each species of mangrove to thrive in their preferred biogeographic zones.

Objective:

Building upon their experience with “Mangrove City”, students will delve deeper into the unique adaptations of plants. Through hands-on observations and research, students will deepen their understanding of plant adaptations and their ecological significance. Students will brainstorm how plant adaptations might provide engineers with inspiration for solving challenges related to climate change.

NGSS Standards and Performance Expectations:

Middle School 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-ETS1-1)
- Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. (MS-ETS1-2)
- Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. (MS-ETS1-3)
- Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. (MS-ETS1-4)

Middle School Physical Science

- Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes. (MS-PS1-6)

Middle School Life Science

- Evaluate competing design solutions for maintaining biodiversity and ecosystem services. (MS-LS2-5)

Middle School Earth and Space Science

- Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. (MS-ESS3-3)

Introduction to Biomimicry for Teachers:

Biomimicry, also known as biomimetics, is the practice of learning from and mimicking the strategies found in nature to solve human design challenges. The term comes from the Greek words "bios," meaning life, and "mimesis," meaning to imitate. It is a discipline that studies nature's best ideas, then imitates these designs and processes to solve human problems.

For example, the structure of a bird's wing has inspired the design of aircraft; the semi-aquatic ability of a water strider has led to the creation of robots that can walk on water; the natural cooling system of termite mounds has been applied in the architecture of buildings to reduce energy consumption; and the sticky pads on a gecko's feet have informed the creation of adhesives that can attach and detach with ease.

Biomimicry goes beyond just using nature as inspiration. It involves an understanding of how organisms function within their ecosystems, leading to sustainable and regenerative designs that can contribute positively to the environment. The central idea is that nature, imaginative by necessity, has already solved many of the problems humans grapple with.

More Biomimicry in Action: <https://www.sciencefriday.com/articles/biomimicry-in-action/>

Procedure at a Glance:

1. Introduction to Plant Adaptations:

- Recap the key concepts from the "Mangrove City" VR module, emphasizing the unique adaptations that help mangroves to survive in coastal environments.
- Introduce students to other plant adaptations - the special features or behaviors that help a plant to survive in its habitat.
- Examples from different habitats around the world can be discussed to bring a broader perspective.

2. Local Plant Exploration:

- Students will go on a field trip to a local park or natural area. They will be divided into small groups and tasked with identifying and observing different plants using their field guides or plant identification apps.
- They should look for signs of plant adaptations (like thick, waxy leaves of a plant to reduce water loss) and note them in their notebooks. Students should be encouraged to draw and describe the plants and their adaptations.

3. Plant Adaptation Research:

- Back in the classroom, each group will choose one plant they found particularly interesting and conduct more in-depth research on it.
- They will explore its specific adaptations, how these adaptations evolved over time, and how they contribute to the ecosystem.

4. Biomimicry Brainstorm:

- After understanding their chosen plant's adaptations, each group will brainstorm ways these adaptations could inspire technological or engineering solutions for challenges related to climate change. They should consider questions like: How could this adaptation help conserve energy or water? How could it contribute to cleaner air or less pollution?

5. Prototype Sketching and Presentation:

- Groups will sketch out their ideas, creating a design inspired by the plant's adaptation that addresses a climate change challenge. They should prepare a brief presentation explaining the plant's adaptation, their research findings, and how they incorporated the adaptation into their design solution.

6. Group Presentations and Reflection:

- Each group will present their findings and designs to the class. After all presentations, the class will discuss the experience, what they learned about plant adaptations, and how nature can inspire us to create innovative solutions to our problems.

7. Extension Activity:

- Students can be encouraged to bring in samples of local plants from their own yards or neighborhoods for additional observation and discussion. They can also look into existing examples of biomimicry in modern technology and design.

Biomimicry Blitz: Exploring Plant Adaptations

FIELD NOTES

Instructions: Document and describe the plants you found on your plant walk. Be sure to look for signs of plant adaptations (like thick, waxy leaves of a plant to reduce water loss) and note them here.

1. Describe the local park or natural area you visited:

Location: _____

Date of Visit: _____

2. For each plant you identify, record the following:

Name of Plant: _____

Observed Adaptations (sketch any interesting features):

Name of Plant: _____

Observed Adaptations (sketch any interesting features):

Name of Plant: _____

Observed Adaptations (sketch any interesting features):

Name of Plant: _____

Observed Adaptations (sketch any interesting features):

Name of Plant: _____

Observed Adaptations (sketch any interesting features):

Biomimicry Blitz: Exploring Plant Adaptations

RESEARCH SUMMARY

Back in the Classroom:

1. Of the plants you identified, which one did you find the most intriguing?

2. Research the plant(s) and answer the following:

- Habitat:

- What role does this plant play in its ecosystem?

- What adaptations has the plant developed over time?

- How could the plant's adaptation inspire technological, or engineering solutions related to climate change? List three ideas:
 - 1.
 - 2.
 - 3.

Biomimicry Design Brainstorm

STUDENT WORKSHEET

Instructions: Collaborate with your group and sketch out a preliminary design for a plant-inspired climate change solution. Be prepared to present your findings to the class:

1. Write down plant-inspired features you wish to include in your product design:

2. Explain how each design feature aligns with plant adaptations you observed or researched:

3. Create a sketch of your prototype to present to the class.

Tips for the presentation:

- Be concise but informative.
- Focus on the major points that led to your proposed solution.
- Encourage and be open to feedback and questions from the class.

Activity 2: Coastal Erosion and the Role of Mangroves

In “Mangrove City,” students practiced planting mangroves in the shallow area in front of the seashore to determine how the presence of mangroves impacts coastal erosion.

Objective:

In this activity, students will further explore the concept of coastal erosion and the significant role mangroves play in preventing it. Students will create a simple model to observe the effects of coastal erosion and how mangroves can alleviate this phenomenon.

NGSS Standards and Performance Expectations:

Middle School Earth and Space Science

- Water’s movements—both on the land and underground—cause weathering and erosion, which change the land’s surface features and create underground formations. (MS-ESS2-2)

Middle School Engineering Design

- Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. (MS-ETS1-4)

Materials Needed:

- Large aluminum pans/trays or clear plastic containers
- Sand
- Soil
- Water
- Construction materials (e.g., clay, craft sticks, sponges, mesh fabric, newspaper)
- Stopwatch
- Rulers
- Science notebook or datasheet for each group

Introduction to Coastal Erosion for Teachers:

Coastal erosion is a natural process that involves the gradual removal of sediments from the shoreline. This process is significantly influenced by wind, waves, tides, currents, and sea-level rise. While coastal erosion is part of the natural dynamics of coastal ecosystems,

human activities and climate change can accelerate it, leading to significant losses of land, damage to infrastructure, and disruption of coastal ecosystems.

Mangroves are unique trees that grow along coastlines in tropical and subtropical regions around the world. These trees are well-adapted to saline environments and are known for their dense, tangled roots which rise above the water level. One of the most crucial ecological roles of mangroves is their ability to prevent coastal erosion.

Mangroves act as a natural barrier, protecting the coastlines from waves and storm surges. Their complex root systems help to trap sediments and slow down water flow, reducing the impact of waves on the shoreline and preventing soil erosion. Furthermore, mangroves also contribute to land stabilization by enhancing sediment deposition.

Procedure at a Glance:

1. Observing Soil Erosion:

- Divide students into groups and provide each group with one container.
- Each group will create a 'sandy shoreline' in their plastic container and simulate conditions of tide, wind, and rain. They should observe and document any changes to the 'coastline' as erosion occurs, particularly noting the degree of erosion.
- Students will simulate a high tide or storm surge by gently rocking each container back and forth. They should observe and note any changes that occur on the 'coastline' over a set period (e.g., one minute) using the stopwatch. They can measure the amount of soil erosion by measuring the change in height or width of the 'coastline' at various points.

2. Problem Identification and Solution Design:

- After observing the erosion, students should brainstorm how they might design a solution that could help prevent this erosion. They should consider the characteristics of mangroves that help prevent coastal erosion, such as their complex root systems and ability to trap and build up sediments.

3. Prototype Development:

- Each group should then select their most promising idea and use the provided materials to build a prototype of their solution. This should be added to a new 'sandy beach' in a fresh plastic container.

4. Testing the Solution:

- Students will again simulate the conditions of tide, wind, and rain, this time to test the effectiveness of their prototype against soil erosion. They should measure the extent of erosion by observing changes in the height or width of the 'coastline' at various points.

5. Data Analysis and Improvement:

- Groups should analyze their findings and identify any areas where their solution could be improved. They should modify their prototypes based on their analysis, then retest their solutions.

6. Presentation and Reflection:

- Finally, each group should present their engineered solution to the class, or complete a reflection worksheet, explaining their design process, how their solution was inspired by mangroves, and how effective their solution was at preventing erosion.

7. Extension Activity:

- Invite students to research real-world examples of biomimicry applied to prevent coastal erosion and share their findings with the class.
- Through this lab activity, students will gain practical experience with the scientific method and the engineering design process, learn more about the role of mangroves in preventing coastal erosion, and discover the potential of bio-inspired solutions to real-world challenges.

Coastal Erosion and the Role of Mangroves

STUDENT WORKSHEET

Part 1: Observing Soil Erosion

Objective: Understand and document the process of soil erosion under simulated conditions.

Materials:

- Plastic container
- Sand
- Stopwatch

Procedure:

1. Create a 'sandy shoreline' in your plastic container.
2. Simulate tide, wind, and rain conditions, observing any erosion that occurs.
3. Simulate a high tide or storm surge by gently rocking your container back and forth for one minute. Use the stopwatch to time this.

Observations:

1. Initial 'coastline' measurements (height/width at various points):
2. Observations during tide, wind, and rain simulation:
3. Observations during high tide or storm surge simulation:
4. Post-simulation 'coastline' measurements:

Coastal Erosion and the Role of Mangroves

STUDENT WORKSHEET

Part 2: Problem Identification and Solution Design

Objective: Reflect on the observed erosion and brainstorm potential solutions inspired by mangroves.

Questions:

1. How did the 'coastline' change during the simulations?
2. How might mangroves help prevent the observed erosion?
3. Brainstorm potential design solutions inspired by mangroves:

1. Sketch your prototype design below:
2. Use the provided materials to build your prototype.
3. Add your prototype to a new 'sandy shoreline' in a fresh plastic container.

Coastal Erosion and the Role of Mangroves

STUDENT WORKSHEET

Part 4: Testing the Solution

Objective: Test the effectiveness of your prototype against soil erosion under simulated conditions.

Procedure and Observations:

- a. Simulate tide, wind, and rain conditions again.
- b. Record observations and measurements of 'coastline' after prototype test:

Part 5: Data Analysis and Improvements

Objective: Analyze your findings and iterate on your design for better results..

Questions:

1. How effective was your prototype in preventing soil erosion?

2. What improvements could be made to your design?

Coastal Erosion and the Role of Mangroves

STUDENT WORKSHEET

Part 6: Presentation and Reflection

Objective: Prepare to present your findings and defend your proposed solution to the class. Afterwards, reflect on the entire process, the effectiveness of your solution, and the inspiration from mangroves.

Questions:

1. Describe the main features of your prototype design.
2. How was your solution inspired by mangroves?
3. How would you further improve your design for real-world applications?

Activity 3: Designing Solutions for Ecosystem Health

In “Mangrove City,” students investigated the intricate relationships between the various organisms in the mangrove ecosystem and how each species contributes to the overall health and balance of the forest. To understand ecosystem services, students looked at the essential roles that mangroves play in providing habitat for a diverse array of species that contribute to the overall biodiversity of the ocean.

Objective:

In this activity, students will conduct research on a specific ecosystem, gaining a deep understanding of its functions, the critical role of biodiversity within it, and the various ecosystem services it provides. As part of their research, they are expected to identify potential challenges to maintaining biodiversity and the provision of ecosystem services, which would then form the basis for brainstorming possible solutions.

NGSS Standards and Performance Expectations:

Middle Life Science

- Evaluate competing design solutions for maintaining biodiversity and ecosystem services. (MS-LS2-5)

Science and Engineering Practices

- Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. (MS-LS2-5)

Disciplinary Core Ideas

- Biodiversity describes the variety of species found in Earth’s terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem’s biodiversity is often used as a measure of its health. (MS-LS2-5)
- Changes in biodiversity can influence humans’ resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling. (Secondary to MS-LS2-5)
- Small changes in one part of a system might cause large changes in another part. (MSLS2-4), (MS-LS2-5)

Materials Needed:

- Computers with internet access
- Notebooks and pens
- Art supplies for creating visuals (optional)

Introduction to Ecosystem Services for Teachers:

Ecosystem services are the numerous benefits we derive from nature that contribute to our well-being and improve the quality of our lives. They are typically divided into four categories: provisioning, regulating, supporting, and cultural services.

1. **Provisioning Services:** These are the tangible goods that ecosystems provide, such as food, water, timber, fiber, genetic resources, and medicinal resources. They are typically the services we can physically touch and consume.
2. **Regulating Services:** These services help regulate environmental conditions. They include air quality regulation, climate regulation (including global scale processes like carbon sequestration), water purification, waste treatment, disease regulation, and pollination.
3. **Supporting Services:** These are the services that enable all other ecosystem services. They are necessary for the production of all other ecosystem services and include soil formation, photosynthesis, primary production, nutrient cycling, and water cycling.
4. **Cultural Services:** These are non-material benefits people obtain from ecosystems, which include aesthetic inspiration, cultural identity, spiritual enrichment, recreation, ecotourism, and mental health improvement.

Understanding these ecosystem services is critical for teaching about environmental sustainability as it allows students to appreciate how human well-being is intimately connected with the health of our ecosystems. It encourages students to consider how their actions may impact these services and how protecting ecosystems is essential for our survival and quality of life.

Procedure at a Glance:

1. Introduction and Group Formation:

- Begin with a brief discussion of ecosystems, biodiversity, and ecosystem services (such as water purification, nutrient recycling, and prevention of soil erosion). Then, divide the students into small teams and assign each team a specific ecosystem to research.

2. Research Phase:

- Each team will use the internet and library resources to research their assigned ecosystem. They should focus on the biodiversity within the ecosystem, the ecosystem services it provides, and the challenges it faces (e.g., climate change, pollution, invasive species).

3. Design Phase:

- Based on their research, each team will brainstorm potential solutions to maintain or improve the health of their ecosystem and its services. They should consider the scientific, economic, and social constraints of each solution.

4. Evaluation and Selection:

- Teams will discuss the merits and constraints of each solution and choose the most promising one. They should consider factors like feasibility, impact, potential unintended consequences, and how well it helps maintain biodiversity and ecosystem services.

5. Presentation Preparation:

- Teams will prepare a short presentation to share their findings and chosen solution with the class. This should include an overview of their ecosystem, the challenges it faces, their proposed solution, and a defense of why they believe their solution is the best option, especially in terms of maintaining biodiversity and ecosystem services.

6. Presentations and Discussion:

- Each team will present their findings and defend their proposed solution. After each presentation, allow time for questions and discussion.

7. Extension Activity:

- After the presentations, facilitate a class discussion on the importance of maintaining ecosystem health and the potential roles students can play in this work in their own communities. This could lead into a service project or other practical application of what they've learned.
- This lesson plan not only provides students with a comprehensive understanding of the dynamics of ecosystems, the importance of biodiversity, and the necessity of maintaining ecosystem services but also encourages critical thinking, research skills, collaboration, and public speaking, aligned with the standard MS-LS2-5.

Designing Solutions for Ecosystem Health

STUDENT WORKSHEET

Part 1: Identifying your Ecosystem

Objective: Understand the importance of ecosystems, biodiversity, and ecosystem services.

Questions:

1. What are ecosystem services, and why are they important?
2. Which ecosystem has your team chosen/been assigned?
3. Describe the primary ecosystem services provided by your ecosystem:
4. Identify and explain three challenges faced by your ecosystem (e.g., pollution, invasive species, climate change):

Designing Solutions for Ecosystem Health

STUDENT WORKSHEET

Part 2: Design Phase

Objective: Brainstorm solutions to enhance the health and sustainability of your assigned ecosystem.

Questions:

1. List potential solutions to maintain or improve the health of your ecosystem
2. Consider the scientific, economic, and social constraints of each solution.
Describe them briefly

Designing Solutions for Ecosystem Health

STUDENT WORKSHEET

Part 3: Evaluation and Selection

Objective: Evaluate the potential solutions and select the most promising one.

Questions

1. Which solution seems the most feasible and impactful for your ecosystem?
Why?
2. Are there any potential unintended consequences of implementing this solution?
3. How does your chosen solution help in maintaining biodiversity and ecosystem services?

Part 4: Presentation Preparation

Objective: Prepare to present your findings and defend your proposed solution to the class. Key points to include in your presentation:

- Overview of the ecosystem.
- Challenges faced.
- Proposed solution and its advantages.
- Defense of why your solution is optimal.

Activity 4: Building Our Classroom Aquaponics System: A Hands-On Lesson in Sustainable Agriculture

In “Mangrove City,” students explored how engineers in “Mangrove City” created aquaponic farms to feed the residents of the city.

Objective:

Aquaponics is a sustainable method of food production that combines aquaculture (raising fish) with hydroponics (growing plants in water without soil). In this interactive lesson, middle school students will learn about aquaponics, design their aquaponics system, and observe how plants, fish, and bacteria interact in a mutually beneficial cycle.

NGSS Standards and Performance Expectations:

Middle Life Science

- The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. (secondary to MS-LS1-6)
- Cellular respiration in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. (secondary to MS-LS1-7)
- Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (MS-LS2-3)
- Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (MS-LS2-4)

Performance Expectations

- Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. (MS-LS2-3)
- Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. (MS-LS2-4)

Materials

- Aquarium tank
- Fish (tilapia or goldfish are commonly used)
- Water pump
- Grow bed (can be a simple plastic container)
- Plants (leafy greens work well in aquaponics systems)
- Gravel or clay pebbles
- Tubing to connect the tank and grow bed
- Water quality test kit

Introduction to Aquaponics for Teachers:

Aquaponics is an innovative, sustainable method of food production that combines aquaculture (the raising of aquatic animals such as fish) with hydroponics (the cultivation of plants in water). It's a synergistic system in which the waste produced by the fish provides organic food for the plants, and the plants naturally filter the water that the fish live in. Additionally, bacteria that naturally occur in the system convert the fish waste into nutrients that the plants can use.

Aquaponics is a fascinating topic for middle school students as it provides a tangible, hands-on way to understand a variety of concepts, including the nitrogen cycle, symbiotic relationships, and sustainable farming. It is an interdisciplinary topic that ties in with biology, chemistry, engineering, and environmental science, promoting a holistic understanding of these subjects.

When teaching aquaponics, it's important to emphasize the sustainability aspect of it. Aquaponics systems use significantly less water than traditional soil farming, they don't require artificial fertilizers or pesticides, and they can be set up almost anywhere, making them an excellent tool for producing food in urban or arid environments. These systems embody many of the principles of a circular economy and offer students a concrete example of how we can design systems that work with nature, rather than against it.

To ensure that the hands-on learning experience is safe and effective, teachers should familiarize themselves with the [basic components of an aquaponics system](#), including the fish tank, grow bed, pump, and piping. Teachers should also understand how to maintain a healthy aquaponics system, including feeding the fish, monitoring the pH and nitrogen levels of the water, and pruning the plants as needed.

Introducing students to aquaponics provides a unique opportunity to engage them in active learning, while also sparking their interest in sustainability and innovation. It

empowers students to be creators and caretakers of a mini ecosystem, fostering their scientific curiosity and environmental stewardship.

Procedure at a Glance:

1. Introduction to Aquaponics:

- Begin with a classroom discussion about traditional farming methods and the challenges they present, such as overuse of water and soil erosion. Introduce aquaponics as a sustainable alternative and explain how it works. Use diagrams to illustrate the cycling of nutrients and the symbiotic relationship between fish and plants.
- Describe the nitrogen cycle, focusing on how it functions within the aquaponics system. Use diagrams to help illustrate the different stages: ammonia to nitrite, nitrite to nitrate, and how plants utilize nitrates for growth.

2. Building the System:

- Under teacher supervision, students will build their aquaponics system/s. This includes setting up the aquarium, connecting the pump to the grow bed, adding the fish, and planting the seeds in the grow bed.

3. Maintaining and Observing the System:

- Over the next several weeks, students will take turns feeding the fish, testing the water quality, and observing plant growth. They will record their observations in a classroom logbook.
- When conducting water quality tests, measure the ammonia, nitrite, and nitrate levels in the system. Explain how these levels reflect the ongoing conversion processes within the nitrogen cycle.

4. Discussion:

- Once the system is running, facilitate a class discussion about the observations made. How are the fish and plants doing? What changes do they observe in the water quality? How do the bacteria contribute to the system? What might happen if any part of the cycle was disrupted? How does this system compare to traditional farming methods?

5. Extension Activity:

- As a homework assignment, students can research different types of plants and fish that can be used in an aquaponics system and propose adjustments or enhancements to their current system design.

- This lesson offers a unique, hands-on opportunity for students to learn about sustainable agriculture and the importance of closed-loop systems. Through this activity, students will gain a deeper understanding of ecosystems and resource conservation.

Maintaining and Observing the System

Below is a recommendation for the classroom observation table. You can adjust the rows/columns accordingly based on the frequency and duration of your monitoring efforts.

Date	Time	Ammonia (ppm)	Nitrite (ppm)	Nitrate (ppm)	Notes
MM/DD/YYYY	HH:MM				
MM/DD/YYYY	HH:MM				
MM/DD/YYYY	HH:MM				
...	...	...	...	...	...

Here's a breakdown of the columns:

- **Date:** The date when the measurement was taken.
- **Time:** The time when the measurement was taken, using a 24-hour format.
- **Ammonia (ppm):** The concentration of ammonia measured in parts per million (ppm).
- **Nitrite (ppm):** The concentration of nitrite measured in ppm.
- **Nitrate (ppm):** The concentration of nitrate measured in ppm.
- **Notes:** A space for any additional observations or important information related to the system's condition, specific plant/fish behavior, or recent changes in the system that might influence the levels of these chemicals.

When using this table, ensure that you have accurate testing equipment that can provide reliable ppm measurements for ammonia, nitrite, and nitrate. Always follow manufacturer's instructions when using testing kits.

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