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Maine Aquaculture: Spotlighting Seaweed Aquaculture and Exploring Careers Across All Aquaculture Sectors



Teacher Edition

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Table of Contents

Maine Aquaculture: Spotlighting Seaweed Aquaculture and Exploring Careers Across All Aquaculture Sectors

Section I: Background Information and References

Section II: Weeks 1 and 2

- Hook Lesson
- Lesson Plans
- Additional Resources

Section III: Weeks 3 and 4

- Lesson Plans
- Additional Resources

Section IV: Weeks 5 and 6

- Lesson Plans
- Additional Resources
- Student and Teacher Reflections

Section V: Additional Resources

Section I

Essential Questions:

How does aquaculture contribute to Maine's economy and environmental well-being?

What are the environmental benefits of seaweed aquaculture, and how does it function?

What potential careers exist in the aquaculture sector, and what skills are required?

Standards	
MS-LS 2-1	Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
MS-LS2-2	Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
MS-ESS3-3	Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

Background Information

For many generations, the coastal areas of Maine have relied on diverse ocean resources to sustain a thriving economy. The lobster industry has been a significant contributor that has intricately woven itself into the fabric of life in these coastal communities, influencing tax revenue, employment, and the state's identity. However, the impact of climate change, leading to rising temperatures in Maine's coastal waters, has instigated significant transformations in the underwater ecosystem and the connected economy (Gulf of Maine Warming Update: 2022 the Second-Hottest Year on Record, 2023). The Gulf of Maine exhibits a warming trend surpassing 96% of the world's oceans, with temperatures increasing by 0.09 degrees annually. This warming has driven the American lobster (*Homarus americanus*) population to migrate northward in search of colder waters, profoundly affecting the livelihoods of Maine fishermen (Oleck, 2023). Concurrently, the accelerated warming has reduced the number of American lobster eggs laid off

the southern coast. This northward migration challenges some lobstermen, leading many to adapt and diversify by transitioning into aquaculture (Gunst, 2022).

Aquaculture is defined as the cultivation, rearing, and harvesting of fish, shellfish, and aquatic plants, essentially it's farming in water (*What Is Aquaculture?* | *National Oceanic and Atmospheric Administration*, 2011). Aquaculture, encompassing seaweed, oysters, mussels, and fish, significantly complements the traditional and thriving practices of lobstering and fishing (Seafood and Aquaculture, n.d.). The aquaculture industry in Maine comprises almost 200 farms and involves over 700 farmers dedicated to cultivating high-quality seafood, including finfish, shellfish, and sea vegetables (Britsch et al., 2021). Sea vegetables are plant and algae foods that grow in or near the ocean. There are over 250 species of seaweed in the Gulf of Maine, 11 of which are commercially harvested. The most common forms of seaweed raised in Maine are sugar kelp (*Saccharina latissima*) and skinny kelp (*Saccharina latissima* forma *angustissima*) (*The Story of a Maine Seaweed Farm: An Evening Harvesting Sugar Kelp with Ridley Cove*, n.d.). Over recent years, this sector has experienced consistent growth, with its overall economic impact nearly tripling.

The cultivation of seaweed is a relatively recent practice. Until the 1950s, the majority of the world's seaweed supply was obtained from wild harvesting. In the 1960s, substantial commercial production began in Asia, marking a period of rapid industry expansion (*Seaweed Aquaculture* | *California Sea Grant*, n.d.). Around 90% of seaweed is cultivated overseas, but the U.S. seaweed market is anticipated to exceed \$5 billion in the next six years. Maine's cultivated seaweed yield has experienced remarkable growth in the past five years. From 2017 to 2022, productivity, effectiveness, and financial gains improved on kelp farms in Maine. Considering the substantial progress observed between the 2017 and 2022 harvesting seasons, the expectation

is that ongoing experience, learning, and scaling efforts will contribute to additional enhancements in the production and economic vitality of the farmed seaweed industry in Maine (Brayden and Coleman, 2023).

Cultivating seaweed is considered a straightforward, versatile, and environmentally beneficial practice for ocean ecosystems, providing an efficient means to produce highly nutritious food to meet the demands of a growing population. Unlike traditional land crops, seaweed cultivation requires no fertilizer, pesticides, freshwater, or dedicated land. Additionally, seaweed exhibits rapid growth, with certain marine algae reaching harvest readiness in just six weeks (Chopin et al., 2001). As an underwater forest, seaweed plays a pivotal role in absorbing carbon, nitrogen, and phosphorus, acting as a valuable tool in mitigating climate change and purifying water, while simultaneously creating new habitats for diverse marine life (Duarte et al., 2017). According to Bolduc et al. (2023), seaweed acts as a natural carbon sink, aiding the ocean in absorbing excess carbon dioxide from the atmosphere

While seaweed has traditionally found use in food and supplements, its applications have diversified into cosmetics, clothing, and bio-plastics. The global seaweed industry offers a wide array of products with an estimated annual total value of \$10 billion (Kim et al., 2019). Approximately 83% of this production is dedicated to sea vegetables for human consumption, with the remaining portion utilized in applications such as fertilizers, animal feed additives, medical uses, and biotechnological applications. The macroalgal production worldwide is experiencing an annual increase of 5.7% (Rebours et al., 2014).

To sustain the growth of seaweed aquaculture, it is crucial to focus on several key aspects. Firstly, there is a need to highlight the environmental advantages associated with seaweed cultivation. Secondly, efforts should be directed towards the domestication of various

local seaweed species. Lastly, the diversification of seaweed products is essential, spanning applications in food, animal feed, bioplastics, cosmetics, and potentially biofuels (Troell et al., 2022). The Gulf of Maine presents significant opportunities for the expansion of seaweed aquaculture (Britsch et al., 2021).

Various educational, research, non-profit, and organizational entities are collaboratively engaging in exploring seaweed aquaculture in Maine. The University of Maine, in conjunction with partners, recently completed research through the SEANET program—a five-year initiative that was dedicated to fostering the development of ecologically sustainable aquaculture in Maine. Ongoing work continues to be conducted at UMaine, specifically in collaboration with Adam St. Gelais from the Aquaculture Research Institute, situated at the Darling Marine Center. This group of researchers has devised a kelp aquaculture model tailored for the Gulf of Maine. This model focuses on optimizing both carbon sequestration and cost-effectiveness, thereby enhancing the role of this natural carbon sink. The concept of cultivating kelp for large-scale carbon dioxide removal has gained considerable attention from the research community, private sector, and aquaculture industry. Their research aims to bring a realistic perspective to discussions on the costs and environmental impact associated with this emerging technology. The Gulf of Maine is increasingly seen not only as a national leader in sustainable seafood production but also as a potential carbon sink (Schipani, 2022). Furthermore, Maine Sea Grant, in collaboration with the Maine Aquaculture Association, CEI, Maine Aquaculture Innovation Center, and Island Institute, has been delivering training on seaweed and shellfish aquaculture to coastal fishing communities through the Aquaculture in Shared Waters program (*Seaweed Aquaculture Industry Overview*, n.d.).

Hook Lesson: Aquaculture Exploration Stations

Objective: Students will gain a comprehensive understanding of aquaculture through interactive and diverse exploration stations.

Students will be grouped in sets of six and will circulate through each station where they will either read or engage in discussions about the presented information. It's important to note that only some stations will be supervised by an adult. Students are advised to bring their Chromebooks and earbuds for the activity. Students will be at each station for 7 minutes. Including introduction, rotation time, and a concluding discussion, this activity will take approximately 90 minutes. It can be done in 2-45 minute class periods as well.

For teachers who are unable to have a large group set-up, this can be done in the classroom with some modifications to each station.

Station 1: Edible Station - "Seaweed Tasting Adventure"

Objective: Students will explore the culinary side of seaweed aquaculture.

- Setup: Arrange a table with different edible seaweed products (snacks, salads, etc.).
- Activity: Students taste various seaweed products and discuss the flavors and textures. Provide information on the nutritional benefits of seaweed.

Products: 12 Tides puffed kelp chips, Gimme roasted seaweed snacks, Kimnori snack sheets, Wang Korean Roasted Seaweed Snacks, Atlantic Farms ready to eat Kelp and Seaweed Burgers (or any variety of foods with seaweed)

As students sample various items, the teacher will provide insights into the ingredients and dive into the historical aspects of seaweed as a food source.

Station 2: Video Station - "Virtual Dive into Aquaculture Farms"

Objective: Students will visually explore seaweed farms through video content.

- Setup: Students will carry their Chromebooks and earbuds with them.
- Activity: Students watch videos that provide insights into the seaweed farming process, from cultivation to harvesting. The videos will be posted on Google Classroom.
- After watching the videos, the students will discuss the videos.

Videos:

[What is aquaculture?](#)

[Be Part of the Change: Work in Aquaculture](#)

[Education through Agriculture: Aquaculture](#)

Discussion: What does aquaculture mean to you?

Station 3: Reading Station - "Seaweed Science and Sustainability"

Objective: Students will dive into written resources to understand the scientific and environmental aspects of seaweed aquaculture.

- Setup: Provide infographics related to seaweed aquaculture.
- Activity: Students read and discuss the provided materials, focusing on the environmental benefits of seaweed aquaculture and the scientific principles involved.
- Students will each write on one sticky note something they took away from the information
- Links to be posted in Google Classroom:
[Maine Seaweed Showcase](#)
[MAA Seaweed Farming](#)
[Seaweed Aquaculture Industry Overview](#)

Station 4: Exploration Station - "Seaweed Touch and Feel"

Objective: Students will have hands-on experience with different seaweed species.

- Setup: Arrange various seaweed samples for students to touch, feel, and observe.
- Activity: Students explore seaweed's different textures, shapes, and colors. Encourage them to compare and contrast different species.
- This activity will develop sensory awareness and identification skills related to seaweed.

Station 5: Artistic Expression Station - "Seaweed Artistry"

Objective: Students will express their understanding of seaweed through artistic creations.

Setup: Provide art supplies such as paper, paints, markers, and glue.

Activity: Students unleash their creativity by creating artwork inspired by seaweed. They can draw, paint, or even make collages that depict the beauty and significance of seaweed in Maine's aquaculture.

Discussion: After completing their artwork, students share their pieces with the group, discussing the elements they incorporated and the message they aimed to convey.

Station 6: The Benefits of Seaweed

Objective: Students will review articles and/or infographics on the benefits of seaweed.

Setup: Display infographics or posters on the benefits of seaweed. Print out the following articles for the students to peruse together. Have a display board available for students to place their sticky notes.

[The Benefits of Seaweed \(And When To Avoid It\)](#)

[Is seaweed good for you? Benefits, nutrition and all else you need to know](#)

[Seaweed Nutrition](#)

Activity: Students should peruse the articles and find one or two interesting facts that they didn't know about seaweed nutrition.

Discussion: Put the fact they chose on a sticky note and place it on the display board.

Station 7: Technology Integration Station - "Interactive Seaweed Apps"

Objective: Students will explore technology applications related to seaweed and aquaculture.

Setup: Provide tablets or access to computers with pre-installed seaweed-related apps.

Activity: Students navigate through interactive apps that offer insights into seaweed cultivation, its applications, and its significance in Maine's aquaculture. Apps may include virtual seaweed farms, educational games, or interactive quizzes.

Discussion: Students discuss their experiences with the apps, sharing what they learned and how technology enhances their understanding of aquaculture.

Station 8: Community Engagement Station - "Aquaculture Impact on Coastal Communities"

Objective: Students will understand the broader impact of aquaculture on coastal communities.

Setup: Display maps, charts, or diagrams showcasing the distribution of aquaculture sites and their impact on local economies.

Activity: Students review materials that highlight how aquaculture contributes to the economic and social fabric of coastal communities. They discuss the positive aspects and potential challenges.

Discussion: Encourage students to reflect on how aquaculture aligns with the sustainability and resilience of coastal communities, fostering a broader understanding of its role in society.

Station 9: Environmental Impact Station - "Seaweed and Ecosystem Health"

Objective: Students will explore the ecological impact of seaweed aquaculture on marine ecosystems.

Setup: Provide charts and diagrams illustrating the interconnectedness of seaweed with marine life.

Activity: Students review materials discussing how seaweed cultivation positively influences marine ecosystems, including its role in carbon sequestration, water purification, and providing habitat for marine species.

Discussion: Engage students in a discussion about the delicate balance between aquaculture and environmental sustainability, encouraging them to consider the ecological benefits of seaweed cultivation.

Station 10: Global Perspectives Station - "Aquaculture Around the World"

Objective: Students will gain insights into aquaculture practices beyond Maine's coastal communities.

Setup: Display a world map highlighting key aquaculture regions.

Activity: Students explore information about aquaculture practices worldwide, understanding the variations in techniques, species cultivated, and the cultural significance of aquaculture in different regions.

Discussion: Foster a conversation about the global impact of aquaculture, encouraging students to compare and contrast practices in Maine with those in other parts of the world.

Links to some of the documents created for these lessons:

[Lesson Documents](#)

[Documents \(Landscape View\)](#)

[Modified Documents for Lessons](#)

Week 1-2: Introduction to Aquaculture in Maine/Background Information

Each activity is designed to be completed within one or two 50-minute periods.

Activity 1: Comparing Aquaculture

- Objective: Students will define aquaculture and explain its importance in sustainable food production.
- Activities:
 - Class discussion on the definition and significance of aquaculture.
 - Students will complete the Know, Want to Learn portions of the KWL chart in their booklets
 - Students turn and talk and then place one sticky note on the class chart
 - Share out several
 - Video presentations showcasing different aquaculture practices in Maine In part from, *Overfishing and Aquaculture (Grades 6-8)*, n.d..
 - [The Faces of Maine's Working Waterfront – Cooke Aquaculture](#) (fish farming)
 - [The Faces of Maine's Working Waterfront: Aphrodite Oysters](#) (cage farming)
 - [Maine Lobster Harvest - America's Heartland](#) (wild caught)
 - Students take notes as they watch the 3 videos.
 - Students complete a Venn Diagram comparing 3 different methods of harvesting fish
 - Introduction to basic aquaculture vocabulary. Have the students complete the vocabulary worksheet in their booklet. Assign a day for a vocabulary quiz.
 - Vocabulary games: such as Trashcan Basketball
 - Divide the class into 2 or 4 teams.

- Have each team take turns answering a vocabulary question.
- If they can answer correctly, the team gets 1 point.
- Then, give that team a ball (a crumpled-up piece of paper will do).
- If the team can make a basket into the trash can, reward the team an extra point.
- Repeat until all vocabulary words have been tested

Activity 2: Marine Ecosystems

- Review ecosystems with the students
- [Marine Ecosystems](#) (“Marine Ecosystems: Sea Urchins, Kelp and Lobster,” n.d)
- Complete the lesson plan on marine ecosystems in Maine developed by the Island Institute, Rockland, Maine Revised and formatted by Maine Agriculture in the Classroom
- Have students play: [Whale Jenga: A Food Web Game](#) (“Whale Jenga: A Food Web Game Activity Summary,” n.d.)
 - follow directions for set up and print off cards
 - Explain to the students that this game is a representation of how seemingly small changes can impact the stability of a whole system.
- Student reflection in the booklet.

Activity 3: Climate Change in the Gulf of Maine and its Impacts

- [Generation Genius Intro to Climate Change Lessons](#) (*Intro to Climate Change Video for Kids | 6th, 7th & 8th Grade Science*, n.d.)
 - Use before video questions to generate a class discussion
 - Watch the Video
 - Have the students complete the “Analyzing Information Note-Taking” form in their student booklet.
 - Discuss the key/important details from the video.
 - How does climate change relate to lobsters, seaweed, and the Gulf of Maine?
 - If time and resources were available, do the DIY experiment with students.
- [Why is the Gulf of Maine warming so fast? | Maine Explained](#) (*Why Is the Gulf of Maine Warming so Fast? | Maine Explained*, n.d.)
 - Watch the video
 - Have the students complete the “Analyzing Information Note-Taking” form in their student booklet.
- [Gulf of Maine, Explained: Causes & Impacts of Rapid Warming](#) (*Gulf of Maine, Explained: Causes & Impacts of Rapid Warming*, n.d.)

- Watch the video
- Have the students complete the “Analyzing Information Note-Taking” form in their student booklet.
- Read the article, “Maine Lobster Harvest Down 5% Amid Warming Ocean, Right Whale Regulations” and complete the “Analyzing Information Note-Taking” form. (*Maine Lobster Harvest - America’s Heartland*, n.d.)
- Class discussion on climate change and the impacts on Maine’s economy and marine environment.

Activity 4: Summative Assessment: FlipGrid Podcast

- Objective: Demonstrate comprehensive knowledge of the impacts of climate change and the decline of lobster populations in the Gulf of Maine through an engaging podcast and a visual representation.
- Students will use Flipgrid for their presentation
- Assignments can also include the creation of an infographic, advertisement, or brochure to give students a choice in presentation.
- See rubric

Week 3-4: Diving into Seaweed Aquaculture

Activity 5: Seaweed Species Identification

- Presentation on common seaweed species in Maine.
- Video: [Gulf of Maine Seaweed Selection with Tidepool Tim](#) (*Gulf of Maine Seaweed Selection with Tidepool Tim*, n.d.)
- Hands-on activity: Seaweed identification practice.
 - Bring in as many types of seaweed as possible
 - Supplement with pictures
- Class Activity: Seaweed Scavenger Hunt
 - Have the students complete the scavenger hunt chart in their booklets
 - Give the students the following resources:
 - [The Maine Ten: Useful species grown or harvested in Maine](#) (*The Maine Ten: Useful Species Grown or Harvested in Maine - Maine Sea Grant - University of Maine*, n.d.)
 - [Harvested Seaweeds of Maine](#) (*Identification | Maine Seaweed Council*, n.d.)
 - [The Algae Index: A Guide to Edible Seaweeds on the Maine Coast](#) (Redmond, 2015)
 - [Guide to Maine Seaweeds](#) (*Guide to Maine Seaweeds*, n.d.)

Activity 6: Seaweed Species Identification Challenge

- Assessment: Seaweed species identification challenges.
 - Assess the students' knowledge of the Maine seaweeds
- Seaweed Ecosystem and Climate Change
 - [Seaweed](#) (*Seaweed*, n.d.)

Activity 7: Modeling Seaweed Aquaculture

Objective: Students will dive deeper into the intricacies of seaweed aquaculture and understand how a seaweed farm works. Possibly in future years, create a kelp nursery and start a kelp line.

- Advanced Seaweed Aquaculture
- Lectures/videos on advanced concepts of seaweed aquaculture.
 - [Kelp Farming Is Maine's New Cash Crop](#) (*Kelp Farming Is Maine's New Cash Crop*, n.d.)
 - [WeGo Episode 4: Kelp Farming on the Coast](#) (*WeGo Episode 4: Kelp Farming on the Coast*, n.d.)
 - [How To Grow Seaweed](#) (*How to Grow Seaweed - YouTube*, n.d.)
- Group discussion on the challenges and opportunities in seaweed farming.
- Students will work together to create a model of a kelp farm on a hallway wall. It will:
 - Represent a marine ecosystem, showcasing various species and their interactions.
 - Provide information on the roles of different organisms in the ecosystem, emphasizing the importance of biodiversity.

Possible extension activities: Visit Atlantic Sea Farms in Biddeford, Maine

Week 5-6: Benefits of Seaweed Farming and Career Exploration

Activity 8: Career Exploration in Aquaculture

Objective: Students will evaluate the benefits of seaweed farming, explore various careers in aquaculture, and emphasize the importance of minimizing human impact.

- Activities:
 - Guest speakers (or online videos) from different aquaculture professions.
 - [Aquaculture in Maine predicted to grow as industry seeks skilled workers](#) (*Aquaculture in Maine Predicted to Grow as Industry Seeks Skilled-Workers*, n.d.)
 - Virtual career exploration using online platforms. Job descriptions.
 - Students start researching and creating fake LinkedIn posts for chosen aquaculture careers.

- [10 of the Most Popular Types of Aquaculture Jobs in 2024](#) (*10 of the Most Popular Types of Aquaculture Jobs in 2024*, n.d.)

Videos on younger workers:

<https://www.youtube.com/watch?v=JgdKplHfc0U> (this has racked up 41k views, wow!)

<https://www.youtube.com/watch?v=jVoUKpz822Q> (full version of video above)

https://www.instagram.com/maine_aquaculture/reel/C0uJ4idLvRP/ (another apprentice)

https://www.tiktok.com/@greenjobs_explained/video/7249828060529200426

Engagement:

- Begin with a class discussion on what students know about aquaculture.
- Introduce the concept of various careers within the aquaculture sector (e.g., marine biologist, aquaculture technician, environmental scientist, farm manager).

Career Exploration:

- Using videos or presentations on different aquaculture careers.
- Discuss the responsibilities, skills, and educational requirements for each role.

Research Assignment:

- Students choose a specific aquaculture career to research.
- Provide online resources or library materials for research.

Creating LinkedIn Profiles

Discussion:

- Review the aquaculture careers discussed in the previous class.
- Emphasize the importance of a professional online presence and networking.

LinkedIn Overview:

- Provide an overview of LinkedIn and its purpose in professional networking.
- Discuss the key elements of a LinkedIn profile (photo, summary, experience, education).

Resume Building:

- Distribute worksheets with sections for personal information, education, skills, and work experience.
- Guide students in creating a basic resume highlighting relevant skills and experiences.

LinkedIn Profile Creation:

- Instruct students to create a simulated LinkedIn account using a designated platform or a template provided.
- Have students input information from their resumes, ensuring they understand the importance of professionalism.

Peer Review and Sharing:

- Allow students to share their simulated LinkedIn profiles with a partner for peer review.
- Encourage constructive feedback on completeness, clarity, and professionalism.

Assessment:

- Evaluate research assignments based on the accuracy and depth of information gathered about the assigned aquaculture career.
- Assess LinkedIn profiles and resumes for completeness, accuracy, and professionalism.

Activity 9: Seaweed and Its Applications

Objective: Introduce students to various products that use seaweed and lay the foundation for creating their own seaweed-based product.

- Introduction:
 - Discuss the diverse applications of seaweed in daily life.
 - [Why Demand For Seaweed Is About To Boom](#) (*Why Demand For Seaweed Is About To Boom*, n.d.)
 - Show images or samples of different seaweed products.
 - [Reading on Uses of Seaweed](#) (*Seaweed.ie:: Uses and Utilization*, n.d.)
- Seaweed Products Scavenger Hunt:
 - Break students into small groups.
 - Each group compiles a list of products found that use seaweed

Seaweed in the Culinary World

- [Sensational Seaweed Culinary Activity](#) (*Sensational Seaweed*, 2019)
- Tasting Session:
 - Allow students to taste dishes prepared with seaweed.
 - Discuss flavors, textures, and nutritional aspects.
 - [Health Benefits of Seaweed](#) (*Eating Seaweed Helps Keep You Healthy It Has Many Benefits*, n.d.)

Exploring Seaweed in Beauty and Wellness

Objective: Expand students' understanding of seaweed applications in beauty and wellness products.

- DIY face mask or soap:
 - Provide materials for students to create their seaweed-based face masks.
 - Discuss the benefits of seaweed for skin health.

Seaweed Mask Activity (*Kelp Curriculum | Maine Aquaculture*, n.d.)

From Page 58 in *With a Little Kelp From Our Friends* by Mathew Bate

1. Grind a few seaweed nori sheets into a powder
2. Mix 1 tablespoon of nori powder with 1 tablespoon of warm water
3. Add 1 teaspoon of honey and 1 teaspoon of aloe vera gel
4. Rub mixture onto face and allow to dry
5. After about 15 min rinse off with some warm water

Lesson Plan: Seaweed Product Creation

Objective:

Students will learn about the versatility of seaweed as a sustainable resource and apply creativity and critical thinking to design and present their seaweed-based products.

- Introduction to Prototyping:
 - Explain the concept of prototyping and its importance in product development.
- Hands-On Prototyping:
 - Provide materials for students to create a prototype of their seaweed-based product.

Materials:

- Seaweed samples (various types)
- Art supplies (markers, colored pencils, paper, etc.)
- Small empty product containers (optional)
- Poster boards or presentation materials

Product Design:

- Provide art supplies and empty product containers.
- Instruct each group to design and create a prototype of their seaweed-based product.
- Emphasize the need for creativity, functionality, and sustainability.

Product Presentation:

- Each group prepares a short presentation explaining their product.
- Presentations should cover the purpose of the product, target audience, ingredients, and environmental benefits.

Gallery Walk:

- Arrange the prototypes and presentations in a gallery-style format.
- Students conduct a gallery walk, observing and taking notes on other groups' creations.

Class Discussion:

- Facilitate a class discussion on the different products, focusing on innovation, feasibility, and sustainability.
- Encourage students to discuss challenges faced and solutions found during the design process.

Assessment:

- Evaluate the presentations based on creativity, clarity, and understanding of seaweed's benefits.
- Assess the prototypes for innovation, functionality, and use of sustainable materials.

Student and Teacher Reflections and Feedback on this Unit

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