**Unit Essential Question:** *How does energy and matter flow within natural and designed ecosystems?*

**Introduction**

In the last task, students explored how photosynthesis and cellular respiration cycle matter and energy through living organisms in an ecosystem. However, this is not the only way matter is cycled in an ecosystem. Earth’s materials can also be cycled through non-living components, like rocks, creating some of the changes students originally observed in the river environment in the Lift-Off Task. Students begin the task by thinking back to this river environment and some of the changes in rock formations they saw, using prior knowledge to consider why these changes occur. After simulating the rock cycle, students model the different processes that cycle Earth’s materials, including how energy drives this process. By the end of this task, students are equipped to consider how the rock cycle may play a role in their aquaponics system.

**Alignment Table**

|  |  |  |  |
| --- | --- | --- | --- |
| **Performance Expectations** | **Science and Engineering Practices** | **Disciplinary Core Ideas** | **Crosscutting Concepts** |
| **MS-ESS2-1.** **Develop a model to describe the cycling of Earth’s materials and the flow of energy that drives this process.** [Clarification Statement: Emphasis is on the processes of melting, crystallization, weathering, deformation, and sedimentation, which act together to form minerals and rocks through the cycling of Earth’s materials.] [Assessment Boundary: Assessment does not include the identification and naming of minerals.] | **Developing and Using Models**   * Develop and use a model to describe phenomena. | **ESS2.A: Earth’s Materials and Systems**   * All Earth processes are the result of energy flowing and matter cycling within and among the planet’s systems. This energy is derived from the sun and Earth’s hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth’s materials and living organisms. | **Stability and Change**   * Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale. |
| **Crosscutting Concepts**   * **Energy and Matter**   + Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. | | | |
| **Equity and Groupwork**   * Work within group roles to model the rock cycle. * Discuss errors in a model. | | | |
| **Language**   * Learn new vocabulary by modeling the terms. * Represent new vocabulary in a visual model. | | | |

**Learning Goals**

This learning task asks students to model how Earth’s materials are cycled through rocks in ecosystems. More specifically, the purpose is to:

* Engage prior knowledge of what causes changes in rock formations, and how few rock-related changes are visible over short durations.
* Simulate the rock cycle, focusing on the processes that cycle Earth’s materials.
* Create a visual model to describe how the flow of energy drives the cycling of Earth’s materials in the rock cycle.
* Critique an incomplete or flawed rock-cycle model to inform revisions of their own model.
* Apply knowledge of the rock cycle processes to an aquaponics system design.

**Content Background for Teachers**

In this task, students continue to explore how matter is cycled and how energy flows within ecosystems. Having already looked at the role of living organisms in these processes, students are now examining the role of non-living components in cycling Earth’s materials.

Rocks and minerals make up the majority of the planet’s mass. They provide homes for organisms, make up much of Earth’s landscape, and provide the basis for Earth’s soil. Thus, rock and minerals are very important! The emphasis in this task is not on the type of rock or mineral, but rather the geoscience processes that form them and break them down. The processes students explore in this task are: the heating and compaction of rock deep underground, the cooling of very hot underground rock, and the physical and chemical breakdown of surface rock by wind and water.

These geoscience procesess are all driven by the flow of energy, which students will study through the crayon modeling activity. Thermal energy from Earth’s interior provides energy in the form of intense heat, which leads to the deformation and crystallization processes of rock formation. Gravitational compaction provides energy in the form of pressure, which leads to the sedimentation process of rock formation. Earth’s rock is also formed and broken down by interacting with other Earth systems, like the atmosphere and hydrosphere; these interactions are ultimately driven by energy from the sun. When rock is exposed to air, wind, or water, this can cause weathering of the rock. Weathering can be both physical and chemical.

Classic Rock Cycle Diagram

In circular motion: Weather & Erosion, sedimentary rocks, heat & pressure, metamorphic rocks, melting, igneous rocks with black arrows and gray arrows pointing to each others in two different directions.When put together, these processes are known as the rock cycle. A classic representation from the NGSS framework is shown in the image to the right. As with most models, this rock cycle diagram can foster some misconceptions. For example, students may think that every rock experiences the same cycle or that the rock cycle occurs in this specific sequence. This model also doesn’t explicitly show interactions with other Earth systems and the role of the Sun’s energy. It is important to recognize and address these limitations as students explore Earth’s cycling of materials. By the end of this task, students should have a more complete picture of how matter is cycled in an ecosystem, through both living and non-living components.

\*\*For more background information, see the Crayon Modeling Resource Card.

**Academic Vocabulary**

* Rock formation
* Weathering
* Erosion
* Pressure
* Heat
* Sedimentation
* Deformation
* Crystallization
* Igneous Rock
* Sedimentary Rock
* Metamorphic Rock
* Rock Cycle
* Gravity

**Time Needed (Based on 45-Minute Periods)**

4.5 Days

* Engage: 0.5 period
* Explore: 1 period
* Explain: 1 period
* Elaborate: 1 period
* Evaluate and Reflection: 1 period

**Materials**

* Unit 3, Task 4 Student Version

Explore (Per Group)

* Modeling the Rock Cycle with Crayons Card (in a sheet protector)
* Crayons (at least two different colors)
* Source of very hot water in container
* Tweezers or small tongs
* Aluminum foil square
* Plastic knives
* Optional: Bring in real rocks as examples of the different types of rocks in the rock cycle

Elaborate (Per Pair)

* Critique, Correct, Clarify – Rock Cycle Model

Evaluate

* Project Organizer Handout

**Instructions**

**Engage**

1. Introduce Task 4: In the last task, we saw how some substances are cycled through living parts of the environment. Think about what you were still wondering about at the end of the last task (look back if you need to). What questions do you still have?
   * Before you pass out their Student Guide, give students time to reflect individually or with a partner about the questions they recorded at the end of the last task. Share a few of these out as a class, using facilitating questions to guide students toward questions that relate to this task.
2. Transition to Task 4: Today we will look at how other matter can cycle through the non-living parts of our environment, specifically through rocks!

* Now pass out the Task 4 Student Guide.

1. In this activity, students think back to the changes they observed in their river environment, using the photos on their Student Guide to remind them. In pairs, ask students to find at least two changes in rock formations that occurred over 200 years. They should record each and explain why they think each happened.
   * You may want to encourage them to refer back to their Task 1 Student Guide for a list of all the changes they originally noticed.
   * Students’ first instinct will be to look for obvious changes (ie. The big boulder in the front right of the photo). Encourage students to consider that the majority of the landscape is made of rock, and to use their own personal experience of the outdoors to help them.
   * Some sample responses may include:
     + The widening of the riverbed is due to continued pressure from the waterfall.
     + The erosion of the rock on the left is due to weathering from wind and rain over 200 years.
   * After pairs brainstorm and discuss, use equity sticks to share out ideas in a class-wide discussion (See “How to Use This Curriculum” for more details on how and why to use equity sticks).
2. The second question that follows asks students to begin thinking about the widening of the riverbed through the lens of **Stability and Change**, which is the CCC for this task. By drawing pictures of the riverbed now, 1 year ago, and 200 years ago, they begin to think about why many of these large-scale changes are only seen over long-term scales (ie. hundreds of years) instead of short-term scales.
   * Keep in mind that at this point some students may show noticeable changes even after one year, even though in reality these changes are likely not visible. They will revisit this concept after they have gathered more information in the *Explore.*

**Explore**

1. Rock is a crucial non-living part of our environments and when it appears to change or go away, as in the pictures above, it doesn’t just disappear! This activity reminds students that the conservation of matter applies in how Earth’s materials, like rock, are *cycled* through an environment.

* Here, students are engaging in the practice of **Developing and Using Models**, using guided instructions to develop a kinesthetic model of the rock cycle. This will set the stage for them to later develop a visual model of their own.

1. Pass out the Modeling Instructions Card and the relevant materials to each group. Assign roles to each group. You may use whatever roles you prefer. We recommend the use of the Materials Manager, Facilitator, Harmonizer, and Recorder.
   * Ask the Facilitator to read the directions and to make sure everyone understands the investigations.
   * Ask the Materials Manager to handle any resources needed to complete the modeling activity.
   * Ask the Harmonizer to make sure that everyone contributes their ideas and that everyone’s voice is heard.
   * Ask the Recorder to make sure the group is recording their observations in their Student Guides.
2. Students model the rock cycle with a focus on the processes rather than the type of rock. As they follow the directions on their resource card, they should answer the questions that are embedded within the procedure as well as their Student Guide.
   * These questions help students focus on the supplementary CCC of **Energy and Matter** as students consider the role of energy in driving each of these processes.
   * Optional: Provide an analogy map like the one shown below so students can clearly understand what the components of the model represent.

|  |  |  |
| --- | --- | --- |
|  | **Part of the Model** | **What It Represents in Real Life** |
| **Weathering** | Crayon Shavings |  |
| Grating the Shavings with a Tool |  |
| Moving the Crayon Shavings |  |
| **Sedimentation** | Layering of Crayon Shavings |  |
| Pressing Down with Fingers |  |
| **Deformation** | Heat from Water |  |
| Partial Melting of Crayon |  |
| **Crystallization** | Heat from Water |  |
| Full Melting and Cooling of Crayon |  |

1. Below is a summary of each process represented in the crayon model:
   * Weathering: Energy from the sun drives weather patterns, which create wind and water. Wind and water can cause both weathering (breaking down of rock into sediments) and erosion (movement of sediments). This is shown in the model as students physically shave the crayon and move the sediments around.
   * Sedimentation: This process includes the layering and compaction of sediments into sedimentary rock. In the model, the pressure of their fingers represents the gravitational compaction that occurs from layering of sediment.
   * Deformation: In deformation, heat and pressure from within the Earth change the chemical composition of rock. In this model, the heat and pressure is represented by the hot water transferred to the crayon “rock” through the aluminum foil.
   * Crystallization: The main difference between this process and deformation is that crystallization entails full melting and cooling of rock, which is again represented by heating the crayon “rock” with the hot water.
   * Optional: Bring in examples of the different types of rock to provide to each group for comparison.
2. The final question asks students to return to the timeline of the widening riverbed from the *Engage*. By examining rock cycle processes at this scale and comparing to the change in rocks they observe in reality, students should be better able to conclude that these processes are always happening but at a rate so slow, they cannot see them in short periods of time.
3. After students complete this modeling activity in small groups and complete the table with their observations, it is recommended that you do a class debrief of the discussion questions. In particular, emphasize how energy (from the Sun and Earth’s interior) drives all of these processes.
   * Use equity sticks to create a more equitable discussion (See “How to Use This Curriculum” for more details).

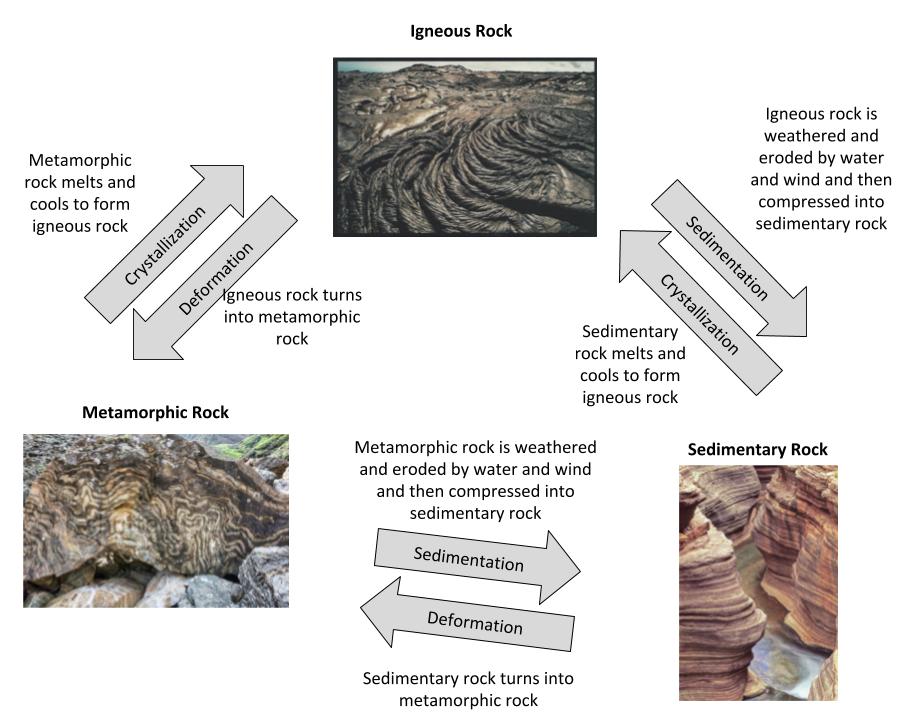
**Explain**

1. Now that students have modeled each of the processes that cycle Earth’s materials with a given procedure, they can turn this into a visual model of the entire cycle.
   * This gives students more practice at **Developing and Using Models**, building off the kinesthetic modeling done in the *Explore* to combine all the processes as part of one cycle. This also emphasizes the supplementary CCC of **Energy and Matter** as students again include the role of energy in driving this cycle.
   * Read the instructions aloud together as a class, emphasizing that students must use all the terms in the box on their Student Guide. Invite clarifying questions before students begin working on models individually.
   * Optional: You may want to model the process of using pictures, labels, and arrows by sketching one component of the model on the board. Pick one type of rock and draw an arrow connecting it to another type of rock. Label the arrow with the name of the process and a caption describing what is needed to cause the transformation.
2. Students create a flowchart model showing how Earth’s materials cycle throughout the environment.
   * For an extra challenge, you may remove, or limit, the list of terms provided.
   * In the final product, specifying the type of rock is less important than an understanding of each process in the rock cycle, including what causes each process to occur.
   * We recommend this model be drawn independently since students have already had a chance to co-construct a kinesthetic model in the *Explore* and this can then be used as a formative assessment of student understanding.

**Elaborate**

1. This activity gives students an opportunity to self-assess and revise their own model based on their critique of a model that has some errors. This activity is a language protocol known as Critique, Correct, Clarify.

* These can be completed in pairs, in groups, or individually. As with the previous section, if done individually, this can be used as a formative assessment.

1. Pass out a *Critique, Correct, Clarify – Rock Cycle Model* to each pair of students. Students will analyze the model to identify and discuss any errors they see, including ideas that are not clear or missing. They then write on the model to make it clearer and more accurate and describe how and why they corrected the model.
   * For students who are struggling, here are some facilitating questions you might ask: Look at your box of terms…what does the model do well? What is the model missing? Where and how would you be better able to incorporate these ideas? Will you change one part of the model or many parts of the model?
   * In their critique, students should notice that all types of rock and processes are identified and explained correctly. However, the role of energy in driving all of these processes is missing throughout the model. This would need to be added into each of the captions. This continues to emphasize the supplementary CCC of **Energy and Matter** as students identify the role of energy driving this cycle that is missing from the model.
   * We recommend sharing out critiques and revisions as a class before students go back to revise their own model in the *Explain* section of their Student Guides.
2. This revised model is a good opportunity for formative assessment. Collect student work to identify trends in students’ ability to develop models of rock cycle processes, including the role of energy in cycling matter. See “How to Use This Curriculum” for strategies on utilizing formative assessment data to provide feedback to students and inform classroom instruction.
3. Return to the whole-class concept map from the Lift-Off Task.

* In small groups, have students brainstorm new concepts and new connections that they have learned in this task, as well as any new questions that have come up for them. Then have groups share these aloud in a class-wide discussion and add to the class concept map. The use of equity sticks is encouraged for more equitable participation in class-wide discussions (See “How To Use This Curriculum” for more details).
  + Some possible facilitating prompts to ask students are: What new ideas/concepts do you want to add to the map? What connections do you want to add or change? What is your reason for that addition/revision? What connections can we make between the questions/ideas already on the map? What new questions do you have about the phenomenon?
  + Draw circles around each question and boxes around each concept.
  + Write connector words to describe connections between the concept boxes.
  + For this task, students may begin to connect some of their previous question circles to concept boxes about the following: how energy drives the cycling of matter through rocks.
* Have students analyze the additions to the class concept map for as many examples of this task’s crosscutting concept as they can find. Once a student has identified the crosscutting concept, you can trace the circle in the corresponding color (decided on in the Lift-Off task). We recommend asking students to share key words that helped them identify the crosscutting concept for that concept or question. Some identifying words students might look for are:
  + **Stability and Change**: These could be phrases such as, “remains the same”, “is changed by”, “is disrupted by”, “changes”, “disrupts,” etc.
* Once again, the purpose of this concept map is to facilitate the generation of student questions, promote language development, and support understanding of the science content throughout the unit. Allowing students to ask their own questions and use their own words to make meaning of the concepts will not only help them make deep connections about science content, but will also help their oral and written language development.

**Evaluate: Connecting to the Culminating Project**

1. Students independently complete the Task 4 section of the Unit 3 Project Organizer in class. Revisions can be done for homework, depending upon student’s needs and/or class scheduling.
2. Students have been tasked with creating a sustainable aquaponics system that mimics the properties of the river environment, including any cycling of matter that occurs through the rock cycle. Their prompt is as follows: Look back at your design sketch for your aquaponics system.

* How might cycling of matter come into play in your aquaponics system?
* Describe which process(es) of the rock cycle might occur in your aquaponics system over time.
* What will the effects be on your system?

**Reflection**

1. At the end of the task, ask students to reflect on what they have learned over the course of this task by answering the following three questions in their student guide:

* At the beginning of this task, you were asked to identify changes in rock formations of the river environment and make hypotheses as to why they happened. Look back at your hypotheses: after exploring the rock cycle today, how would you change or add to your response? Use evidence from the task to justify your changes or additions and record below.
* In this task, we focused on the crosscutting concept of **Stability and Change**: Stability and change can be explained by looking at changes over time and at different scales. Where did you see examples of **Stability and Change** in this task?
* Now that you have learned more about how rocks also cycle matter in ecosystems, what questions do you still have?

1. There are no right answers, but encourage students to look back at their Student Guides and their class concept map. They should not change their initial responses, but rather use this reflection space to add to their ideas and questions based on what they have learned through this task. By generating more of their own questions, students continue to engage in sense-making of the phenomenon and gathering knowledge and skills for their final projects.

**Assessment**

1. You may collect students’ Project Organizer and assess using:

* *Criteria of your choice.* We recommend using the 3-Dimensional Assessment matrix at the beginning of this document to inform your criteria.
* This can be a formative tool to periodically look for trends in student understanding after the completion of a task. You can then use this formative data to inform any re-teaching as necessary.

1. You may also give students time to make revisions with one of the two options:

* Students may make changes to their Project Organizer according to your comments OR
* Ask students to exchange Project Organizers with a partner and give partners 5 minutes to give written feedback. Then allow students time to make changes to their work according to the feedback.