



The Missing Water of Mars

Grades 11-12

Lesson Duration: 5, 50 min periods

AP Environmental Science

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BIG IDEAS

- **Earth's water cycle is dynamic:** The hydrologic cycle, powered by the energy of the sun, moves water in solid, liquid, and gaseous phases between Earth's atmosphere and on/underneath the Earth's surface
- **Earth's water cycle consists of interlocking processes:** The hydrologic cycle has the following process which work together to continuously move water around the planet: evaporation, transpiration, condensation, precipitation, runoff, and infiltration
- **Mars was once covered by water, but its water loss is linked to atmospheric changes:** Historically, the surface of Mars was covered by liquid water, but changes during the planet's history, including the loss and thinning of its atmosphere and conversion to a cracked, desert surface over time caused water to either evaporate into space or seep into deep reservoirs under Mars' surface
- **Human activity and climate change currently and will continue to impact Earth's water cycle:** Deforestation, agricultural practices, and the rise in global temperature can alter the hydrologic cycle, leading to desertification and reduced water availability, a phenomenon which is mirrored by Mars' history

EDUCATION STANDARDS

AP Environmental Science Course Framework (College Board, 2020)

Unit 1 The Living World: Ecosystems

Topic 1.7 The Hydrologic (Water) Cycle

- **Enduring Understanding ERT-1:** Ecosystems are the result of biotic and abiotic interactions
- **Science Practice 2.B:** Explain relationships between different characteristics of environmental concepts, processes, or models represented visually: in theoretical contexts and in applied contexts

- **Learning Objective ERT-1.G:** Explain the steps and reservoir interactions in the hydrologic cycle.
- **Essential Knowledge:**
 - **ERT-1.G.1:** The hydrologic cycle, which is powered by the sun, is the movement of water in its various solid, liquid, and gaseous phases between sources and sinks.
 - **ERT-1.G.2:** The oceans are the primary reservoir of water at the Earth's surface, with ice caps and groundwater acting as much smaller reservoirs.

Science and Engineering Practices:	Disciplinary Core Ideas:	Crosscutting Concepts:
<p>Developing and Using Models:</p> <ul style="list-style-type: none"> • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. <p>Analyzing and Interpreting Data:</p> <ul style="list-style-type: none"> • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution <p>Constructing Explanations:</p> <ul style="list-style-type: none"> • Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena 	<p>ESS2.C: The Roles of Water in Earth's Surface Processes: The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.</p>	<p>Structure and Function: The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.</p>

ELA: Tennessee English 11-12 Standards (Tennessee Department of Education, 2017)

- **11-12.RI.KID.1** Analyze what a text says explicitly and draw inferences; support an interpretation of a text by citing and synthesizing relevant textual evidence from multiple sources.
- **11-12.RI.CS.4** Determine the meaning of words and phrases as they are used in a text, including figurative, connotative, and technical meanings; analyze how an author uses and refines the meaning of a key term or terms over the course of a text.

MEASURABLE STUDENT LEARNING OBJECTIVES

Students will be able to:

- Analyze and interpret data to generate questions and an initial model about the change in surface waters on Mars
- Create a model describing the major steps of the hydrologic (water) cycle
- Collect data in order to analyze the current and historical distribution of water on Mars
- Describe human impacts and environmental factors that influence the hydrologic cycle in order to predict changes to Earth's water cycle based on evidence from Mars
- Create a final model to answer the research question: *What could have caused Mars to lose its surface water?*

MATERIALS NEEDED

- Access to a technology (computer, tablet, phone)
- Copies of handouts
 - Link to all handouts:
<https://docs.google.com/document/d/1IA4hhff9gzsZuzbdQ8TUBALjw9zK-PD2ude8IjNjDNM/edit?usp=sharing>
 - Handout A: Surface Water on Mars & Initial Model
 - Handout B: Water Cycle Model
 - Handout C: Investigating the Water Cycle of Mars
 - Handout D: Desertification Infographic & Rubric
 - Handout E: Missing Water on Mars - Final Model

ENGAGING CONTEXT/PHENOMENON

The engaging phenomenon for this learning sequence is a combination of images and animation from NASA Goddard showing the simulated ocean coverage on the surface on Mars and the current surface of Mars (available here: **Handout A: Surface Water on Mars**). Students are asked to follow the *See-Think-Wonder* (Project Zero, 2022) protocol as they make observations of the changes in water content on the surface of Mars. Throughout this learning sequence, students will be investigating two questions: the overarching question, ***What could have caused Mars to lose its surface water?*** and the secondary question, ***Could changes that occurred to Mars' water cycle potentially mirror future changes to***

Earth's water cycle? Using these two questions, students will learn about the processes of Earth's water cycle, the changes in water on Mars, and relate the changes on Mars to changes that are currently impacting Earth's water cycle and/or could potentially impact Earth's water cycle in the future as our climate continues to change.

DATA INTEGRATION

This lesson involves students analyzing data from a variety of sources, presented in a multitude of formats, from readings, to diagrams, to videos. In some lessons, students are given data to analyze, such as in the introduction to the phenomenon of Mars' missing water, which uses still images gathered from NASA's Mars Reconnaissance Orbiter, MAVEN, and Viking Orbiter. In others, students are tasked with researching and analyzing data they find on their own, such as what they will do when investigating Mars' history and water cycle, using data collected by NASA's InSight Lander. Students will be tasked with synthesizing content learned from several different sources to fully model their answer to the overarching research question, **What could have caused Mars to lose its surface water?**

Suggested sources are presented throughout each individual sequence and hyperlinked on each handout. A sample of sources are listed below:

- Still photos obtained from the NASA video, Measuring Mars' Ancient Ocean: <https://www.youtube.com/watch?v=WH8kHncLZwM>
- Data presented regarding adding on the "loss through atmosphere" hypothesis from NASA: <https://www.nasa.gov/solar-system/new-study-challenges-long-held-theory-of-fate-of-mars-water/>
- Infographic on the connection between Martian dust storms and accelerated water loss from NASA: <https://svs.gsfc.nasa.gov/13771/>

TEACHER BACKGROUND KNOWLEDGE

Earth's water cycle is powered by the sun. As water increases in temperature, it goes through a phase change from liquid to gas in a process called **evaporation**. As plants photosynthesize, they must exchange carbon dioxide and oxygen with the atmosphere through stomata. However, every time that stomata are opened, water escapes to the atmosphere through **transpiration**. As water rises higher in the atmosphere, it cools and **condenses** to form water vapor or clouds. Eventually, water falls back to the Earth as a form of **precipitation** (e.g., snow, rain, sleet). When rain falls on land or an impervious surface such as concrete, it can run off the surface, in a process called **runoff**. However, if it falls on land and goes into the ground, through a process of **infiltration**, it can enter groundwater or aquifers that exist below ground.

However, humans are impacting the water cycle through processes such as building more impervious surfaces, deforestation, or desertification. Less green spaces with vegetation means that rain is less likely to infiltrate into the ground and is more likely to increase runoff and increase the risk of flooding and water pollution by carrying pollutants across surfaces into rivers, lakes, and streams. As our climate warms and trees begin to be negatively impacted, less transpiration occurs, which ultimately reduces the amount of water vapor cycling through the atmosphere leading to more accumulation of water in reservoirs, such as lakes or the ocean (the ocean storing most of Earth's water). Additionally, snow and ice in cooler climates begins to melt, adding water to bodies of water, such as lakes or oceans.

Scientists at NASA have abundant evidence that Mars was once covered in water (Steigerwald, 2001). It has been assumed that the Earth and Mars were created with the same amount of water. However, the surface of Mars and Earth look very different today.

There are two hypotheses of where Mars' surface water went and why there are only small trace ice caps left behind on the planet today. The first hypothesis supposes that as Mars' atmosphere thinned over time, UV rays from the sun were able to split water and hydrogen could escape Mars' gravity and exit its atmosphere. The second hypothesis supposes that as Mars' surface cooled over time, cracks formed in the rocky surface which allowed the water to seep deeper below the crust and become trapped far beneath the surface where it still resides today (Hautaluoma, Johnson, & Good, 2021). Taken together, both of these hypotheses provide evidence that, as Mars turned into a cold, desertified planet, its ancient water cycle was disrupted, and its surface changed from an ancient ocean to a rocky surface with traces of water that used to be.

For additional background information, see the following:

Water Cycle:

- <https://gpm.nasa.gov/education/water-cycle>
- <https://www.noaa.gov/jetstream/atmosphere/hydro>

Impacts to Earth's Water Cycle:

- <https://scied.ucar.edu/learning-zone/climate-change-impacts/water-cycle-climate-change>
- https://oehha.ca.gov/media/downloads/ecotoxicology/fact-sheet/watercyclefacts_0.pdf

Changes to Mars' Surface Water:

- <https://www.caltech.edu/about/news/what-happened-to-marss-water-it-is-still-trapped-there>
- <https://www.nasa.gov/solar-system/new-study-challenges-long-held-theory-of-fate-of-mars-water/>

DIFFERENTIATION OF INSTRUCTION

- Students will have access to technology (laptops, tablets, phones) during the lesson. Students will have access to both physical and digital copies of all handouts and graphic organizers allowing them choice in either writing or typing notes, responses, etc.
- To assist in the creation of their initial and final models of the phenomenon, sample diagrams and a list of questions/considerations/must-haves are presented for students to think about and utilize.
- While watching videos, closed captioning should be used to allow all students to access the material. Additionally, hyperlinks for all resources, including videos, should be posted to an online platform accessible to students so they can re-watch videos as well as use assistive text readers, online reading software, enlarged text, etc.
- In their infographic project, students have a choice in the medium of expression, allowing all students to differentiate their individual voice and creativity. For students who may need assistance in laying out their project, a sample template is provided.

REAL-WORLD CONNECTIONS FOR STUDENTS

The thought of living on Mars, or terraforming, is an exciting prospect that has been discussed for a long time in the news and media, especially as NASA joins other space agencies to consider the prospect of life on Mars. This lesson intends to investigate the science behind a very real consideration for that prospect – is there water on Mars and, if so,

how do scientists tap into it for potential use? Additionally, this lesson lays the groundwork for current science aiming at trying to understand if there is any (potential for) life on Mars, trapped away in the water underneath the planet's crust.

Closer to home, this lesson sequence highlights the importance of the water cycle and ways in Earth's water cycle may be impacted by human activity and climate change. Water is extremely important to every community, even if they do not live by the ocean or a large body of water. In a large city like Nashville, it is important for students to consider the water cycle and how urbanization has – and continues to – impact the movement of water around the city. Furthermore, as climate change continues to impact our current and future condition, it is important to understand how loss of water resources and land resources (such as forests) can lead to the acceleration of desertification, a major impact to Earth's water cycle and a process that Mars underwent as its atmosphere thinned. This lesson aims to connect the general excitement with space exploration and the thought of either life existing or humans living on Mars, with impacts on Earth, and the importance of water – the key to life.

However, like all science lessons, it is critically important to humanize science with students. While this lesson is designed to investigate the science behind the water cycle, it would be remiss to not address the connections various groups of people have and continue to hold and form with water and the ecological services it provides. Science is not neutral and nor is it removed from place. This lesson – like all lessons – must frame students' funds of knowledge, by focusing on the relationships and responsibilities between people and place – where are students engaged in science, how are they engaged in science, and to what end and with what considerations are they engaged with science (Bang, Marin, & Medin, 2018). To that end, it is my recommendation that, when considering the importance of the water cycle, students engage in a conversation about what they know about the water, their connections are to it, its importance for people and places, and the ecosystem services water provides.

POSSIBLE PRIOR or MISCONCEPTIONS

Most students will have (at some point) learned a basic overview of Earth's water cycle and Mars, however, there are some misconceptions which may surface throughout the lesson sequence:

- **Mars never had water, nor does it have water currently** – Students may be unaware that Mars was covered with liquid water, including rivers/lakes/oceans. Due to the fact that most of the surface of Mars is red (and not blue like the color of the water on Earth), students may believe that Mars never had water, nor does it have any currently. Instead, there is significant evidence of water on Mars in the past and there is current evidence of water frozen in polar ice caps on Mars today.
- **Water disappears when it evaporates** – Students may assume that because the phase change is invisible, water simply disappears as it goes through evapotranspiration. Additionally, students may believe that the water simply disappeared into space on Mars, rather than understanding that the water went through chemical decomposition and exited Mars' atmosphere.
- **Water only evaporates from oceans/lakes and only impacts temperate, forested areas** – Most water cycle diagrams usually talk about evaporation from oceans and neglect to discuss transpiration from land and other plant sources. Additionally, due to the fact that most examples/images show forested areas, students may not be aware of the importance of and/or impacts of the water cycle in other climates/biomes.

- **Desertification only applies to deserts** – Simply due to the fact that the term is desertification, students may only think that desertification is a process in the desert. However, desertification is the general term given to any climate in which land is overused, arid, and deforested/stripped of plants such that the dirt no longer retains water/moisture.

LESSON PROCEDURE

5E	<p align="center">Details of 5E Lesson Implementation (Visit BSCS to learn more about the 5E instructional model)</p>
<p><u>Engage</u></p>	<p>Lesson Objective: SWBAT analyze and interpret data to generate questions and an initial model about the change in surface waters on Mars</p> <p>Standards Addressed:</p> <ul style="list-style-type: none"> • ERT-1.G.1: The hydrologic cycle, which is powered by the sun, is the movement of water in its various solid, liquid, and gaseous phases between sources and sinks. • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution <p>Materials & Resources:</p> <ul style="list-style-type: none"> • Handout A, Surface Water on Mars & Initial Model: https://docs.google.com/document/d/1IA4hhff9gzsZuzbdQ8TUBALjw9zK-PD2ude8lJnDNM/edit#bookmark=id.v14fz7g9pzw • NASA Video, Measuring Mars' Ancient Oceans: https://www.youtube.com/watch?v=WH8kHncLZwM <p>Procedure: Students will be introduced to the phenomenon of the disappearance of water on the surface of Mars. Students will use two maps and a video from NASA to observe changes in surface water. The NASA video (linked above) should be shown to students first, with students only watching from 2:33 - 2:55 min. This segment of the video shows the change in water on the surface of Mars animating the two static images on the student handout. It may be worth to show the video to students multiple times; first, just to watch and observe and then again to allow them to think about the probing questions, outlined below.</p> <p>Students will use a <u>See-Think-Wonder protocol</u> (Project Zero, 2022) to guide their analysis. For each image, students will individually observe what similarities or differences they see between each growth condition (What do you see?) and reflect on those observations (What do you think about that?). Then, they will share with their group and identify some questions they have or avenues they might need to</p>

investigate (What does it make you wonder?).

After students have had an opportunity to discuss their observations with their group, the teacher should lead a class discussion around the central research question: **What could have caused Mars to lose its surface water?**

Formative/Summative Assessments:

Students will be provided with a graphic organizer to help organize their observations and questions regarding the disappearance of water on Mars. The questions students generate will help guide understanding throughout the unit as they uncover how the water cycle works along with factors that disrupt the water cycle. These initial questions are formative in nature, as they will launch student progression throughout this learning segment.

Then, students will complete an initial model in which they will diagram what they think could have happened to the surface water on Mars, showing the progression from before water loss, during water loss, to after water loss (current conditions). Students should think about visible and invisible forces, e.g., the shrinking of water cover (shown in the video, a visible observation) and the role of Mars' atmosphere (an invisible force). Students will hold on to this model to add to during and revised at the end of this lesson sequence.

Modifications:

This introductory lesson engages students in the *See-Think-Wonder* thinking protocol. If students are not familiar with this resource, teachers should model a sample protocol to help students work through the following questions: What do you see? What do you think about that? What does it make you wonder?

- *Example:*

- What do you see? *Something that looks like ice is at the pole at all times*
- What do you think about that? *Mars' atmospheric and/or surface temperature has to be cold enough for ice*
- What does it make you wonder? *What is the surface temperature of Mars*

Students should be given time to individually write down their observations and questions before sharing out with a partner using the protocol.

Students are given a model template to use in creating their initial model. The emphasis should not be on getting the model correct, but instead making student thinking visible on the model, showing processes that could impact the change on water coverage. Students may benefit from example models, which can be easily found via a Google search for scientific/biological/earth science models.

<p><u>Explore</u></p>	<p>Lesson Objective: SWBAT create a model describing the major steps of the hydrologic (water) cycle</p> <p>Standards Addressed:</p> <ul style="list-style-type: none"> • ERT-1.G.1: The hydrologic cycle, which is powered by the sun, is the movement of water in its various solid, liquid, and gaseous phases between sources and sinks. • ERT-1.G.2: The oceans are the primary reservoir of water at the Earth’s surface, with ice caps and groundwater acting as much smaller reservoirs. • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. <p>Materials & Resources:</p> <ul style="list-style-type: none"> • Handout B, Water Cycle Diagram: https://docs.google.com/document/d/1IA4hhff9gzsZuzbdQ8TUBALjw9zK-PD2ude8lJnDNM/edit#bookmark=id.bmhbidqqo29c • NSF Video, How the Hydrologic Cycle works: https://youtu.be/al-do-HGulk • NASA Video, Earth’s Water Cycle: https://youtu.be/oaDkph9yQBs <p>Procedure:</p> <p>During this phase, students will use a model template from USGS to draw and understand the major processes of Earth’s hydrologic cycle. Students will begin by watching a short video from the National Science Foundation explaining the major steps of the hydrologic cycle (linked above). Students should be prompted to take notes using the guided notes on the bottom half of Handout B (linked above), identifying and describing the major processes of the water cycle.</p> <p><i>However, it is my strong recommendation that before discussing the water cycle, students engage in a framing conversation about what they know about the water, their connections are to it, its importance for people and places, and the ecosystem services water provides.</i></p> <p>After watching the video, students should work in groups to fill out any</p>

missing information they have. At this point, the teacher can also assist in helping students complete their descriptions as needed. Students should then use the blank USGS model to draw and label those steps onto the blank model.

To wrap up this segment of the lesson, students will watch another video from NASA (linked above) which covers a quick review of the steps of the water cycle, but more importantly introduces a multitude of NASA data and introduces an overview of how NASA's satellites gather and monitor data on Earth's water resources.

Upon conclusion of watching the video, students should be posed with a question such as: ***If NASA can monitor Earth's water, can we monitor/predict water on Mars? And, if so how? What data might we want to collect?*** Students should identify TWO sources of data they want to investigate in the next segment of the lesson. This review question is intended to connect and bridge Earth's water cycle with the disappearance of water on Mars.

Formative/Summative Assessments:

During this lesson, students will discuss the final questions: ***If NASA can monitor Earth's water, can we monitor/predict water on Mars? And, if so how? What data might we want to collect?*** The teacher should circulate the room to listen into students' conversations and prompt them to connect it back to the major processes of the water cycle they discovered in both videos and some of the data monitoring sources introduced in the NASA video. As appropriate, students should share their thinking with the whole class.

Modifications:

Subtitles should be used on both videos to assist all students while watching the video.

Some students may benefit from sentence frames to probe their thinking and help launch discussion. Sample ideas/probing questions are included underneath the discussion questions on Handout B. These prompts may also be used to assist in whole class discussion. Some of those include:

- *NASA uses satellites and sensors to monitor Earth's water cycle. Scientists might be able to monitor Mars' water cycle by...*
- *To predict the presence of water on Mars, we might look for evidence of...*

Explain

Lesson Objective: SWBAT collect data in order to analyze the current and historical distribution of water on Mars

Standards Addressed:

- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution
- Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena
- **11-12.RI.KID.1** Analyze what a text says explicitly and draw inferences; support an interpretation of a text by citing and synthesizing relevant textual evidence from multiple sources.
- **11-12.RI.CS.4** Determine the meaning of words and phrases as they are used in a text, including figurative, connotative, and technical meanings; analyze how an author uses and refines the meaning of a key term or terms over the course of a text.

Materials & Resources:

- **Handout C, Investigating the Water Cycle of Mars:**
<https://docs.google.com/document/d/1IA4hhff9gzsZuzbdQ8TUBALjw9zK-PD2ude8lJnDNM/edit#bookmark=kix.tvv8iaa1gmgf>
- **Suggested Video, NASA Has Found Oceans of Liquid Water on Mars:** https://youtu.be/KOTxzi_CqFU

Procedure:

This portion of the lesson directly connects with the conclusion of the previous lesson, namely where students discussed: If NASA can monitor Earth's water, can we monitor/predict water on Mars? And, if so, how? What data might we want to collect?

Additionally, students were asked to identify two sources of data they need to look at/investigate in order to fully answer the overall research question in their final model. In this section of the lesson, students will navigate a series of online sources to investigate their data and help answer their questions. Although students are free to use a variety of sources, suggested sources are provided to help them in answering their questions, such as sources from NASA's InSight Lander. Students should use the supplied graphic organizer from Handout D (linked above) to help organize and keep track of their research.

The teacher should circulate to assist students in navigating online research sources, tracking student progress, and answering students as necessary.

At the conclusion of the lesson, the suggested video linked above should be showed for students, which overviews the two current hypotheses for the disappearance of Mars' water – a key to fully helping students answer the overall research question, ***What could have caused Mars to lose its surface water?***

Formative/Summative Assessments:

The answers generated from this activity will be used by students in their final models, a summative assessment for this lesson sequence. Students should use the graphic organizer from this lesson to assist in creating their final models.

Modifications:

Students may require assistance with finding, reading through, and analyzing NASA (and/or other) research sources. Additionally, students may need help identifying high-quality and reliable sources. Some potential, high-quality sources have been linked on the handout for students.

To help organize their research, it is encouraged that students use the supplied graphic organizer which contains some probes for student thinking.

Elaborate

Lesson Objective Describe human impacts and environmental factors that influence the hydrologic cycle in order to predict changes to Earth’s water cycle based on evidence from Mars

Standards Addressed:

- **ESS2.C: The Roles of Water in Earth's Surface Processes:** The abundance of liquid water on Earth’s surface and its unique combination of physical and chemical properties are central to the planet’s dynamics.
- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution
- **11-12.RI.KID.1** Analyze what a text says explicitly and draw inferences; support an interpretation of a text by citing and synthesizing relevant textual evidence from multiple sources.
- **11-12.RI.CS.4** Determine the meaning of words and phrases as they are used in a text, including figurative, connotative, and technical meanings; analyze how an author uses and refines the meaning of a key term or terms over the course of a text.

Materials & Resources:

- **Handout D, Desertification Infographic & Rubric:**
<https://docs.google.com/document/d/1IA4hhff9gzsZuzbdQ8TUBALjw9zK-PD2ude8lJnDNM/edit#bookmark=id.udtleyuwvhvqa>

Procedure:

In this lesson, students will investigate desertification, a process similar to the changes that have occurred on Mars over time. Students will research desertification and create an infographic describing causes and effects of the process, impacts to the water cycle, and potential solutions to desertification. Students have freedom in choosing the medium for their infographic, whether that be a poster/flier, mixed/visual media presentation, short story, etc. Ultimately, this

lesson has two aims: (1) for students to understand a major human impact to the water cycle and (2) for students to consider if changes that occurred to Mars' water cycle could potentially mirror future changes to Earth's water cycle. A sample rubric is included in the Handout D document, linked above.

Finally, students will produce and present their final design product in a gallery walk/public share out.

Formative/Summative Assessments:

Students will be assessed via their infographic. Their infographic will contain the following sections:

- Define desertification and describe what causes it
- Locate where on Earth this is currently an issue and where it could be an issue/concern in the future
- Describe at least 2 impacts desertification has on the land and connect them to processes of Earth's water cycle
- Describe potential solutions to the impacts of desertification you identified
- Make connections between Mars' water history and Earth's future water story - could we use Mars as a predictive model.

The format of this product will be open to allow for student choice and creativity. Students will publicly display their products in a gallery walk format so students can learn different impacts from each other. Students will score each other's products using a rubric (linked in Handout D, above), emulating a process of peer review.

Modifications:

Students may require assistance with finding mitigation plans, reading through them, and analyzing their use. Additionally, students may need help identifying high-quality and reliable sources. Some potential, high-quality sources have been linked on the handout for students.

Students may additionally need a template to help them organize their information and communicate it in their final design product. Use of the sample template is encouraged.

Evaluate

Lesson Objective SWBAT create a final model to answer the research question: What could have caused Mars to lose its surface water?

Standards Addressed:

- Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
- Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena

Materials & Resources:

- **Handout E, Final Model:**

<https://docs.google.com/document/d/1IA4hhff9gzsZuzbdQ8TUBALjw9zK-PD2ude8lJnDNM/edit#bookmark=id.7sv5gv8omswb>

Procedure:

To wrap up the unit, students will be creating a final model to explain the overall question: **What could have caused Mars to lose its surface water?** Although students will be submitting their models individually, they are encouraged to discuss and work together on producing/revising/editing their models. Additionally, it is highly encouraged that students use their initial model to help in completing their final model.

Formative/Summative Assessments:

The summative assignment for this learning sequence is students' final models.

Modifications:

To assist student understanding of the phenomenon and the research question, as well as the construction of their final models, a list of "must haves" are included on Handout E. This handout is the exact same template as they used at the beginning of the lesson sequence, which is included to provide a way for students to organize their understanding, but also help them in identifying how their understanding and thinking has changed over time.

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