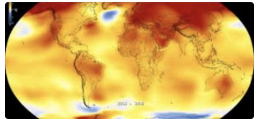
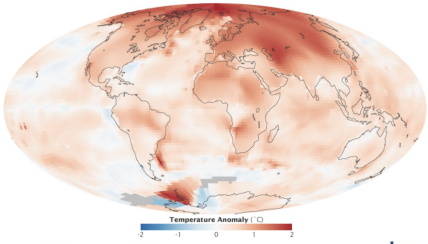
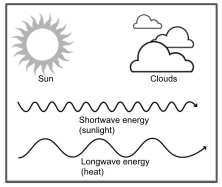
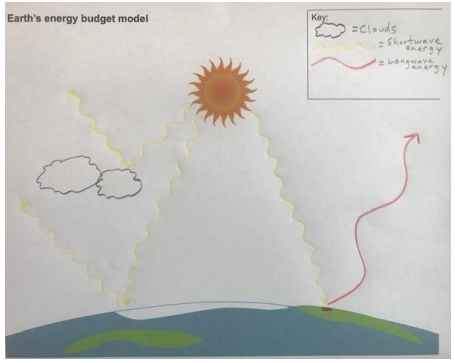
STORYLINE

Unit Driving Question: Why might the Arctic be warming twice as fast as the rest of the world?

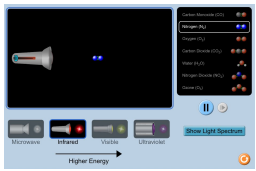
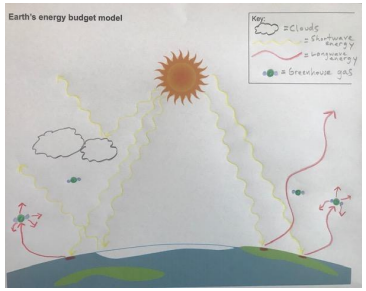
How students will engage with each lesson

Lesson Question	What we do	What we figure out	Connection to unit driving question
Lesson 1 - Eliciting Ideas About A Phenomenon (Arctic Amplification) 2 days **Why might the Arctic be warming four time as fast as the rest of the world?** Anchoring Phenomenon	Develop an initial model to explain why the Arctic is warming twice as fast as the rest of the world (change).  Watch **this video** to observe changes in global temperatures.	The Arctic is warming at a rate faster than the rest of the world.	Initial model examples 

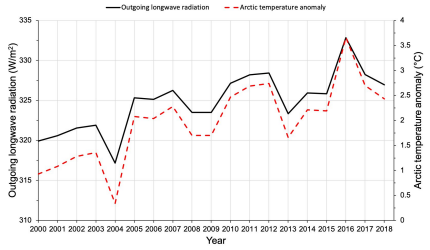
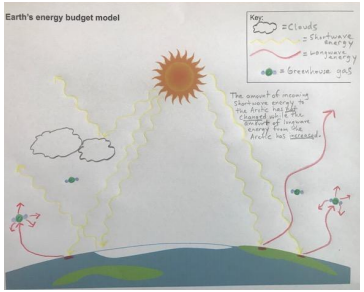
Navigation to Next Lesson: In this lesson, we figured out that the Arctic is warming at a rate faster than the rest of the world. This made us wonder what is causing this amplified warming in the Arctic. In the next lesson, we'll explore the concept of Earth's energy budget through a Google Slides presentation and conceptual modeling exercise.

Lesson 2 - Earth's Energy Budget 1 day **How does Earth maintain the perfect balance of energy?** Gathering Evidence	Communicate the process by which energy enters and exits Earth's atmosphere by creating a conceptual model to represent Earth's energy budget. 	Earth's energy budget describes the balance between the energy that is reaching the Earth from the Sun and the energy that is flowing back out into space from the Earth. Rising global temperatures suggest that Earth's energy budget is imbalanced.	

Navigation to Next Lesson: In this lesson, we figured out that global temperatures are rising which tells us that Earth's energy budget is imbalanced. This made us wonder what factors might be causing this imbalance. In the next lesson, we'll explore the greenhouse effect by engaging with a PhET simulation.

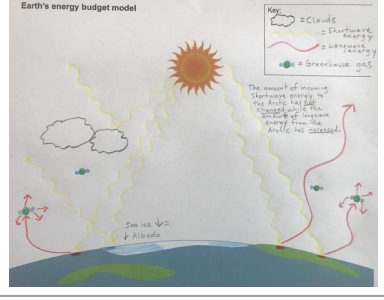
Lesson Question	What we do	What we figure out	Connection to unit driving question
Lesson 3 - Greenhouse Effect 1 day **What characteristics define a greenhouse gas?** **What is the greenhouse effect?** Gathering Evidence	Evaluate how different molecules found in Earth's atmosphere interact with energy of different wavelengths (longwave and shortwave) through a PhET simulation. 	Shortwave energy passes through greenhouse gases (e.g. CO_2, H_2O, CH_4) Greenhouse gases absorb and reemit longwave energy (preventing some energy from passing through Earth's atmosphere) Atmospheric concentrations of greenhouse gases are rising	The greenhouse effect is causing global temperatures to increase. 

Navigation to Next Lesson: In this lesson, we figured out that greenhouse gases absorb and reemit longwave energy (greenhouse effect) and that the concentration of greenhouse gases in Earth's atmosphere is rising. This made us wonder if the greenhouse effect is contributing to the amplified warming in the Arctic. In the next lesson, we compare atmospheric greenhouse gas concentrations around the globe and engage with a virtual reality tour of the Arctic and authentic datasets to determine how the amount of incoming and outgoing energy to and from the Arctic has changed over time.

Lesson 4: Arctic Fieldwork 1 day **How has the amount of shortwave and longwave energy coming and going from the Arctic changed over time?** Gathering Evidence	Analyze and interpret shortwave and longwave energy data from the Arctic (collected by NASA satellites) to evaluate changes in the Arctic energy budget.	Over the 20 years, the amount of incoming shortwave energy to the Arctic has not changed while the amount of outgoing longwave energy from the Arctic has increased. 	Increasing longwave radiation (heat) emitted from the Arctic seems to be related to rising Arctic temperatures. 

Navigation to Next Lesson: In this lesson, we figured out two things. First, the greenhouse effect is contributing to warming globally; however, it alone cannot explain the amplified warming in the Arctic. Second, the amount of outgoing longwave energy (heat) from the Arctic has increased over the past 20 years and appears to be related to rising Arctic temperatures. This made us wonder why the Arctic is emitting more longwave energy (heat). In the next lesson, we revise our initial models representing the unit driving question to incorporate new evidence/understandings gathered throughout the previous lessons.

Lesson Question	What we do	What we figure out	Connection to unit driving question
Lesson 5 - Model Revision 1 day **Why do scientists continue to gather evidence and revise models of phenomena?** Formative Assessment	Develop a revised model to explain why the Arctic is warming twice as fast as the rest of the world (change).		Revised model examples
Navigation to Next Lesson: In this lesson, we reflect on the previous lessons and new understandings to revise our initial models representing the unit driving question, "Why might the Arctic be warming four times as fast as the rest of the world?" This made us wonder why the Arctic is emitting more longwave energy (heat) as was discovered in lesson 4. In the next lesson, students explore the concept of albedo by engaging with the "Albedo: A Reflectance App".			

Lesson 6 - Measuring Albedo 1 day **What is the relationship between the color of a surface and its albedo?** **What happens to energy that is not reflected by a surface?** Gathering Evidence	Conduct an investigation to produce albedo data students will use as evidence to argue that lighter colored surfaces reflect more energy than do darker colored surfaces.	Albedo = Reflectance Lighter colored surfaces have a higher albedo than darker colored surfaces Energy that is not reflected is absorbed causing the temperature of that surface to increase.	As sea ice declines and more ocean is exposed, the albedo of the Arctic decreases and the ocean absorbs more energy (heat) 
Navigation to Next Lesson: In this lesson, we figured out that lighter colored surfaces (e.g., ice) have a higher albedo than darker colored surfaces (e.g., ocean water). We also figured out that energy that is not reflected off a surface is absorbed by that surface. This made us wonder how the decline in Arctic sea ice is affecting the albedo of the Arctic. In the next lesson, students In the next lesson, students analyze and interpret sea ice extent, albedo, and temperature datasets from the Arctic to confirm/refute their ideas related to the ice-albedo feedback and Arctic amplification.			

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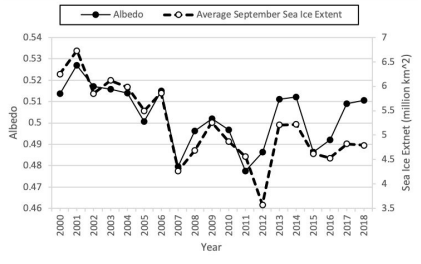
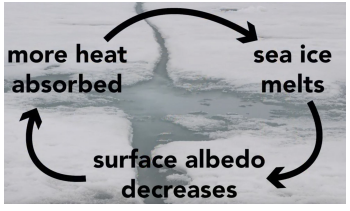
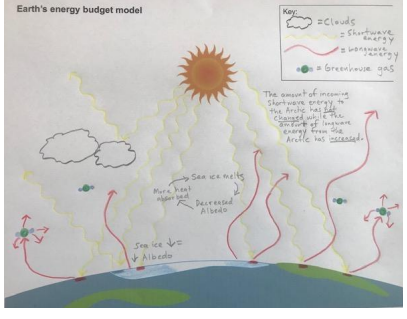
Lesson 7 - Ice-Albedo Feedback 1 day **What is a feedback loop?** **How does a decline in sea ice lead to further melting of sea ice?** **Can we use real-world data to confirm or refute our model/understanding of the unit driving question?** Gathering Evidence	Analyze and interpret Arctic albedo, sea ice extent and temperature datasets to argue the ice-albedo feedback is amplifying (change) warming in the Arctic. 	 Arctic albedo and sea ice extent are directly related with one another. The decline in the Arctic's albedo is one factor contributing to the rise in Arctic temperatures. However, in addition to changes in albedo, there are likely other factors (e.g., changes in ocean/atmospheric circulation patterns) contributing to Arctic amplification.	The Arctic is warming in response to an enhanced greenhouse effect. But that warming is amplified by the ice-albedo feedback. 

Navigation to Next Lesson: In this lesson, we figured out that the melting of sea ice leads to a decline in the Arctic's albedo by exposing more of the darker ocean. A decline in albedo results in more energy being absorbed, leading to an increase in temperatures and further melting of sea ice (ice-albedo feedback). This made us wonder how the ice-albedo feedback and enhanced greenhouse effect might be causing the amplified warming in the Arctic. In the next lesson, students reflect on will analyze and interpret sea ice extent, albedo, and temperature datasets from the Arctic to confirm/refute their ideas related to the ice-albedo feedback and Arctic amplification.

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Lesson 8 - Putting the Pieces Together 1 day **What evidence have we gathered to answer/explain the unit driving question?** Gathering Evidence 	Reference empirical evidence and scientific reasoning (obtained from previous lessons) to argue that the enhanced greenhouse effect coupled with ice-albedo feedback is amplifying (change) warming in the Arctic.	We have lots of data to support our explanation for the amplified warming phenomenon: Arctic temperature, sea ice extent, albedo, greenhouse gas concentrations, incoming shortwave and outgoing longwave energy. There are many ways to represent ideas and datasets symbolically in a final model (annotated sketch) representing Arctic amplification	The Arctic is warming in response to an enhanced greenhouse effect. But that warming is amplified by the ice-albedo feedback.

Navigation to Next Lesson: In this lesson, we reflect on the previous lessons to organize our ideas and evidence for the unit driving question, “Why might the Arctic be warming four times as fast as the rest of the world?” This made us wonder what factors, other than the greenhouse effect and ice-albedo feedback might be contributing to the amplified warming in the Arctic. In the next lesson, we will construct final descriptive models for the unit driving question, “Why might the Arctic be warming four times as fast as the rest of the world?”

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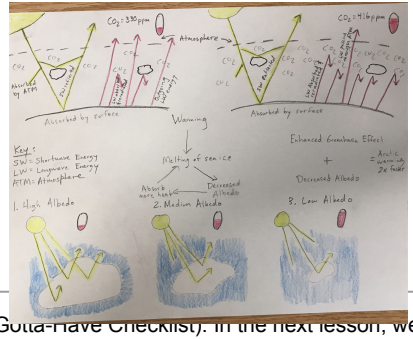
Lesson 9 - Final Model Construction 1-2 days **Why do scientists continue to gather evidence and revise models of phenomena?** Assessment	Develop a final model to explain why the Arctic is warming twice as fast as the rest of the world (change).	Establish concepts and evidence important in explaining the unit driving question, "Why might the Arctic be warming four times as fast as the rest of the world?"	Final model examples 
Navigation to Next Lesson: In this lesson, we figured out which concepts and evidence are important in explaining the unit driving question (see Gotta-Have Checklist). In the next lesson, we will refer to the Gotta-Have Checklist to individually develop written explanations for the unit driving question.			

Lesson 10 - Final Explanation 1 day **Why might the Arctic be warming four times as fast as the rest of the world?** Assessment	Construct an explanation based on qualitative and quantitative evidence for why the Arctic is warming twice as fast as the rest of the world (change).	The greenhouse effect is responsible for rising global temperatures and contributing to a decline in sea ice. The decline in sea ice kickstarts the ice-albedo feedback, the mechanism driving Arctic amplification.	Final written explanation examples
Fin.			