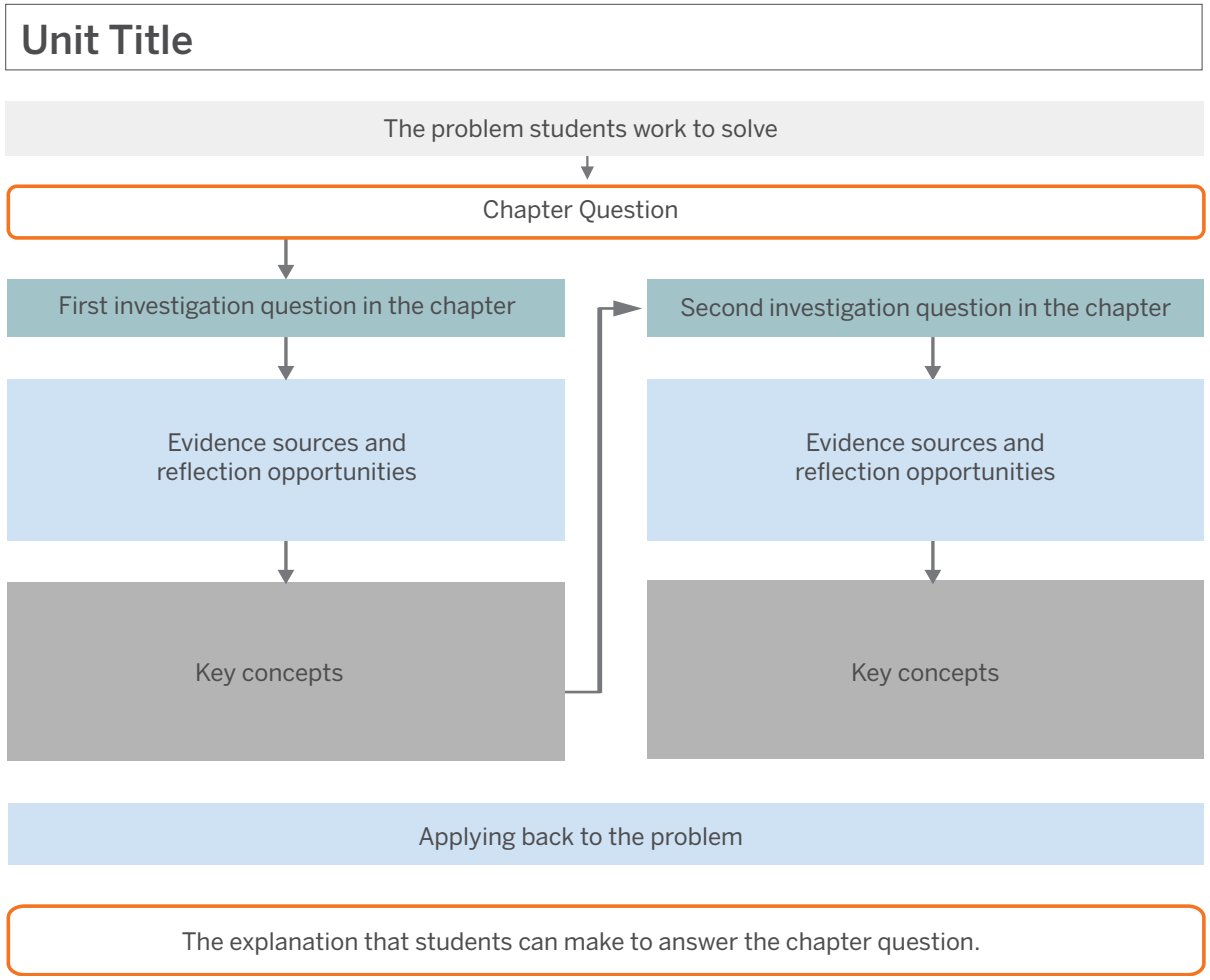
Phase Change Coherence Flowchart

The storyline of the unit

In each Amplify Science unit, students figure out a phenomenon by asking questions, gathering evidence, and coming up with an explanation of how the phenomenon works. The Coherence Flowchart visually represents the storyline of the unit, showing the coherent flow of questions, evidence, and ideas that support students as they build complex explanations of the unit's anchor phenomenon. The Coherence Flowchart on the following pages (one chapter per page) can be used to see the connections between the questions that drive students' experiences, the evidence they gather, the ideas they figure out, and the new questions that those ideas generate. The diagram to the right explains the structure of a chapter in the Coherence Flowchart.

Note: The Coherence Flowchart is a tool for teachers and is not meant to be distributed to students.

Typical structure of one chapter in a Coherence Flowchart



Instruction is framed by questions about the unit's anchor phenomenon and the related problem students are solving. Chapter Questions then guide students in figuring out the phenomenon, piece by piece. Within each chapter, Investigation Questions focus students on a manageable piece of content that will help them figure out the Chapter Question. Each question motivates activities, and each activity provides specific evidence related to the Investigation Question. Students synthesize the understanding constructed over multiple activities, and this understanding is formalized through key concepts. Often a key concept leads students to an additional Investigation Question students need to pursue to answer the Chapter Question. At the end of the chapter, students' new understanding is applied back to the unit's anchor phenomenon and leads students to a new Chapter Question or a final explanation.

AmplifyScience

Phase Change: Titan's Disappearing Lakes

Problem students work to solve

Why did the methane lake on Titan disappear?

Chapter 1 Question

What happened to the liquid in Titan's lake?

Investigation Questions

How does the appearance of a substance change when it changes phase? (1.2)

What happens to the molecules of a substance when it changes phase? (1.3-1.6)

Evidence sources and reflection opportunities

- Observe phase change videos (1.2)
- Discuss the properties of substances in different phases using unit vocabulary (1.2)

- Observe evaporation and condensation and draw predictions of what a solid, liquid, and gas looks like at the molecular scale (1.3)
- Use the Sim to investigate phase changes at the molecular scale (1.3)
- Read an article from *Weird Water Events* (1.4)
- Revisit an excerpt from *Weird Water Events* (1.5)
- Use the Modeling Tool to show what happens to an ice pop when it melts (1.5)

Key concepts

- A solid holds its shape and does not take the shape of its container. (1.2)
- A gas has no visible shape and fills its container. (1.2)
- A liquid flows and can take the shape of its container. (1.2)

- A solid keeps its shape because its molecules only move in place, not around each other. (1.5)
- A liquid can flow because its molecules move around, not away from each other. (1.5)
- A gas does not have a visible shape because gas molecules can move away from each other. (1.5)
- A phase change is when the molecules that make up a substance experience a change to their freedom of movement. This phase change involves a macro-scale change in appearance. (1.5)

Application of key concepts to problem

- Use the Modeling Tool to show what would happen if the lake on Titan froze or evaporated and write a short explanation to support each model (1.6)

Explanation that students can make to answer the Chapter 1 Question

The methane lake on Titan began as a liquid. The liquid methane could flow because the molecules can move around one another, but not apart from one another. If the lake froze, the liquid methane would become a solid. Solid methane would keep its shape because the molecules in a solid can only move in place, but they cannot move around one another or apart. If the lake evaporated, the liquid methane would have become a gas. Methane gas would not have a visible shape because gas molecules can move away from one another.

Phase Change: Titan's Disappearing Lakes

Problem students work to solve

Why did the methane lake on Titan disappear?

Chapter 2 Question

What could cause liquid methane to change phase?

Investigation Questions

What can cause molecules' freedom of movement to change? (2.1)

Why can transferring energy into or out of a substance change molecules' freedom of movement? (2.2-2.3)

Evidence sources and reflection opportunities

- Use the Sim to model and analyze examples of phase changes from the *Weird Water Events* article set (2.1)
- Use the Modeling Tool to model energy transfer and changes to freedom of movement described in *Weird Water Events* (2.1)

- Investigate how transfer of energy affects kinetic energy, temperature, and freedom of movement in the Sim (2.2)
- View, discuss and write about the video, *Zooming in on Phase Changes* (2.2)

Key concepts

- When energy is transferred to or from a substance, it can change the molecules' freedom of movement. (2.1)

- Temperature is a measure of the average kinetic energy of the molecules of a substance. (2.2)
- Transferring energy to a substance increases the kinetic energy of that substance's molecules. Transferring energy from a substance decreases the kinetic energy of that substance's molecules. (2.2)

Application of key concepts to problem

- Analyze evidence about the conditions on Titan over a seven year cycle (2.3)
- Write an argument about what happened to the lake on Titan (2.3)

Explanation that students can make to answer the Chapter 2 Question

If the lake on Titan evaporated, energy would have to have been transferred into the methane. This would increase the kinetic energy of the methane molecules. Eventually this could increase the molecules' freedom of movement and the methane could change from a liquid to a gas. If the lake on Titan froze, energy would have to have been transferred out of the methane. This would decrease the kinetic energy of the methane molecules. Eventually this could decrease the molecules' freedom of movement and the methane could change from a liquid to a solid.

Phase Change: Titan's Disappearing Lakes

Problem students work to solve

Why did the methane lake on Titan disappear?

Chapter 3 Question

Why didn't the liquid methane change phase before 2007?

Investigation Questions

- Why does an energy transfer not always result in phase change? (3.1-3.2)

How does molecular attraction affect whether or not a phase change will occur? (3.2-3.3)

Evidence sources and reflection opportunities

- Read "Liquid Oxygen" (3.1)
- Revisit "Liquid Oxygen" (3.2)
- Investigate phase change with a hands-on experiment (3.2)

- Use the Sim to make and test predictions about energy and phase change based on molecular attraction (3.2)
- Watch video about attraction, kinetic energy, and phase change (3.3)
- Discuss attraction, kinetic energy, and phase change using unit vocabulary (3.3)

Key concepts

- Whether or not a phase change occurs is determined by the interaction between the kinetic energy of the molecules and the attraction pulling the molecules together. (3.2)
- The molecular attraction of a substance never changes. (3.2)

- A phase change occurs when the kinetic energy increases enough to overcome the attraction between molecules. (3.3)
- A phase change occurs when the kinetic energy decreases enough so that the attraction between molecules pulls them together. (3.3)
- Different substances can have either weaker or stronger molecular attraction. (3.3)

Application of key concepts to problem

- Model why the liquid methane lake did not evaporate between 2002 and 2007 (3.3)
- Write an explanation about why the methane lake did not change phase before 2007 (3.3)

Explanation that students can make to answer the Chapter 3 Question

In 2007, the attraction between the molecules of methane in the lake was holding them together. When the sun transferred energy into the liquid methane, the molecules began to increase in kinetic energy, but this was still not enough to overcome the molecular attraction or change the molecules' freedom of movement. In 2009, the methane was invisible and floating in the atmosphere of Titan. The molecules could move away from one another. Sometime between 2007 and 2009, enough energy must have been transferred into the methane lake for the kinetic energy of the molecules to overcome the attraction holding them together.

Phase Change: Titan's Disappearing Lakes

Problem students work to solve and the Chapter 4 Question

Why is the liquid oxygen machine producing less liquid oxygen than normal?

Application of key concepts to new problem

- Explain attraction and kinetic energy in the liquid oxygen machine (4.1)
- Model ideas about kinetic energy and attraction in the liquid oxygen machine (4.1)
- Analyze and sort evidence based on claims (4.2)
- Participate in the Science Seminar (4.3)
- Reason about evidence and claims (4.4)
- Write arguments to support one claim (4.4)

Explanation that students can make to answer the Chapter 4 Question

One possible explanation students can make:
The liquid oxygen machine is producing less oxygen because some of the liquid oxygen evaporated in tank 3. Normally, the temperature of tank 3 increases a little bit, and the nitrogen evaporates into a gas, leaving just the liquid oxygen. This time tank 3 was slightly above its normal temperature, which means more energy was transferred in than usual. Oxygen evaporates at only a slightly higher temperature than liquid nitrogen, so it's possible that this extra energy was enough for the kinetic energy of the oxygen molecules to overcome their attraction, and some of the liquid oxygen evaporated into a gas.