BSCS
A SCIENCE EDUCATION CURRICULUM STUDY

# Strategies for Effective Science Teaching:
# **The Student Thinking and Science Content Storyline Lenses**
# **Grade 5**

## STeLLA Conceptual Framework

**Student Thinking**

Learning to analyze science teaching through two lenses

**Science Content Storyline**

allows you to learn and use strategies for more effective science teaching.

### Science Teaching

#### Strategies to Reveal, Support, and Challenge Student Thinking

1. Ask questions to elicit student ideas and predictions.
2. Ask questions to probe student ideas and predictions.
3. Ask questions to challenge student thinking.
4. Engage students in analyzing and interpreting data and observations.
5. Engage students in constructing explanations and arguments.
6. Engage students in using and applying new science ideas in a variety of ways and contexts.
7. Engage students in making connections by synthesizing and summarizing key science ideas.
8. Engage students in communicating in scientific ways.

#### Strategies to Create a Coherent Science Content Storyline

A. Identify one main learning goal.

B. Set the purpose with a focus question or goal statement.

C. Select activities that are matched to the learning goal.

D. Select content representations and models matched to the learning goal and engage students in their use.

E. Sequence key science ideas and activities appropriately.

F. Make explicit links between science ideas and activities.

G. Link science ideas to other science ideas.

H. Highlight key science ideas and focus question throughout.

I. Summarize key science ideas.

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## How to Learn from Lesson Analysis: The Basics

In this professional development program, you'll be viewing videos of classroom teaching and interviews with students and teachers, as well as answering questions that are designed to help you deepen your understanding of science and science teaching by guiding you to become more analytical about science lessons. You'll also learn to analyze science teaching by focusing your attention on two key issues: student thinking and the science content storyline. These two ways of looking at science teaching will be discussed later. For now, we need to establish some important ground rules—viewing basics for watching the videos and analysis basics for how to begin analyzing video-recorded science teaching in this program.

### Viewing Basics

#### *Viewing Basic 1: Look Past the Trivial, or Little Things, That Bug You*

Keep in mind that real teachers and students are recorded in the classroom videos. Because they're human, they might do things you find annoying or frustrating. For example, a teacher might have certain mannerisms that annoy you or a high-pitched voice that irritates you. She may repeat the same phrase over and over ("OK" or "good" or "like"). He might seem too energetic and silly, or too boring and monotone for your taste. But mannerisms and word choice aren't essential features for high-quality science teaching. Learn to look past them.

You should also not expect perfect, television-quality camera work. Classrooms are very difficult places to video record, and the videographers are trying to capture the real thing in real time, not a staged lesson on a controlled set. For these lessons, the priority was to get the best possible sound quality from students and show exactly what they were seeing and doing during the activities. To capture all of this, the videographers had to move quickly from one part of the classroom to another. You'll begin to appreciate this reality style of videography as you work with the videos.

#### *Viewing Basic 2: Avoid the "This Doesn't Look Like My Classroom!" Trap*

It's unlikely that the student populations and physical facilities you see in the video clips will exactly match your own classroom. A classroom might be in an inner city or a rural area; the class might be a charter school where students call teachers by their first names, or it might be a school where the science-resource teacher doesn't know all of the students' names. Because of this, it might be tempting to say, "These kids aren't like my students, and my classroom doesn't have these resources, so this lesson doesn't speak to my situation." But every teacher needs to understand the science content, use that knowledge to develop a coherent science storyline in the lessons, and pay attention to students' thinking and learning. These are the essentials of science teaching, and they apply to all students in all kinds of communities.

#### *Viewing Basic 3: Avoid Making Snap Judgments about the Teaching or Learning in the Classroom You're Viewing*

As you watch classroom videos, it's easy to make quick judgments about the teacher, the students, and the classroom environment. These judgments can be either positive—"I really like how the teacher conducted that activity"—or negative—"The teacher never uses any wait time; she always rushes the students." Remember you're viewing only a brief snapshot of classroom interactions, so it's dangerous to generalize that "the teacher always does this" or "the students always do that" from a few minutes of video. Also, it's not always helpful to focus on what you like or don't like about what you see and hear. When watching a video, it's best to base your ideas on specific observations and evidence, which you'll learn more about as you examine the STeLLA lenses and strategies.

## Analysis Basics

### *Analysis Basic 1: Focus on Student Thinking and the Science Content Storyline*

Your learning will be maximized if you limit your focus to a close scrutiny of student thinking and the development of the science content storyline in the lessons. Set aside for later your interest in other important issues, such as classroom management and gender equity. As you observe interesting moments in a video or find you have a question or judgment, make a note of it. This will become your claim.

### *Analysis Basic 2: Look for Evidence to Support Any Claims*

Another key step in video-based lesson analysis is the identification of specific evidence to support your claims. As you look at video clips of student work, get in the habit of identifying specific time markers and statements the teacher or the students make that support your thinking about an event. Referring to video transcripts is essential in this process.

- **Claim:** It seems like Miriam doesn't really understand the idea of plants being producers.
- **Evidence:** At video segment 16:54, the teacher comes over and asks Miriam to explain her diagram of matter in a food web. Miriam says that the plants take in matter from the soil and pass it along to the mouse.

### *Analysis Basic 3: Look More Than Once*

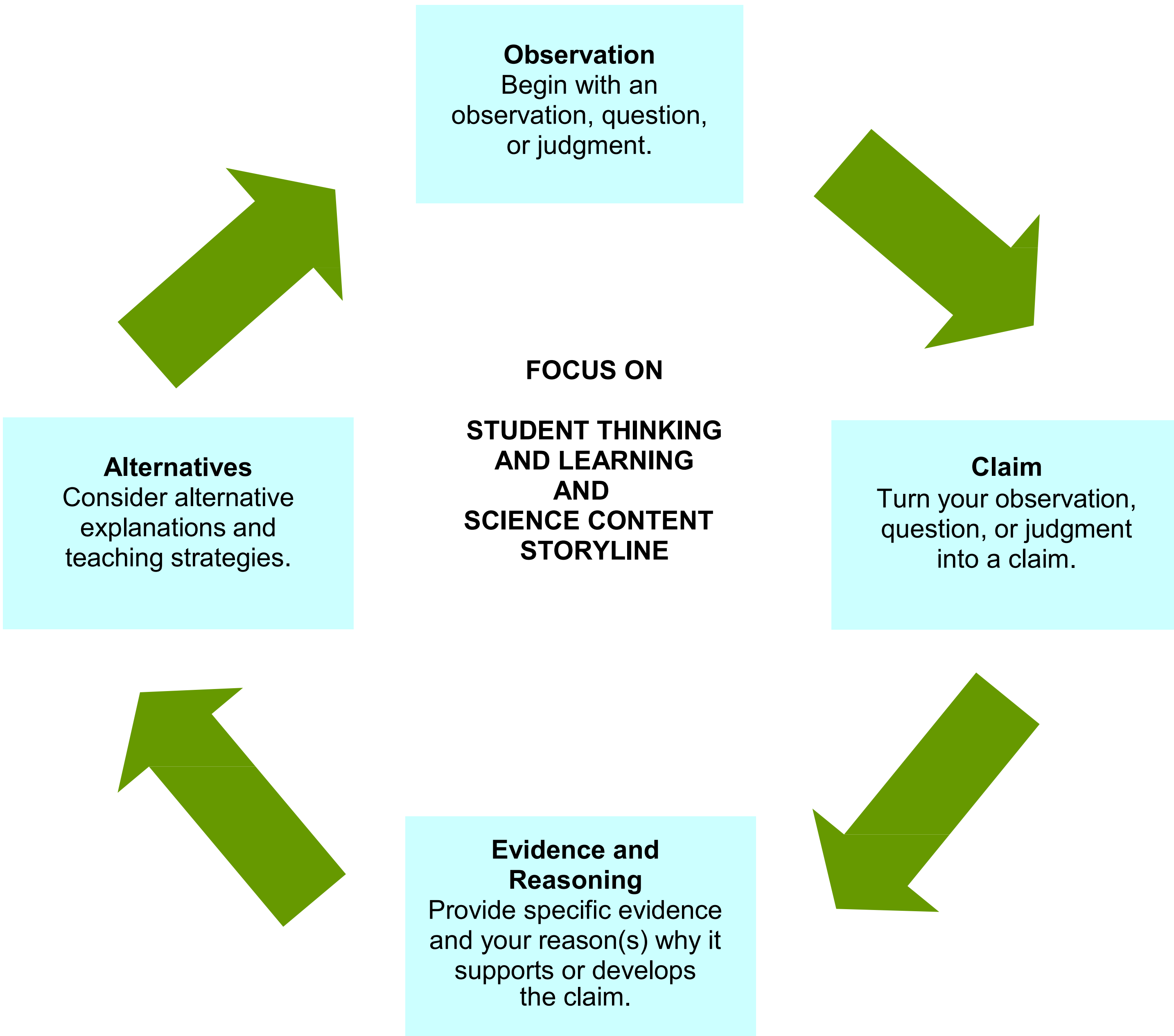
Video recording enables us to look at a teaching episode over and over. Take advantage of this opportunity. To deepen your learning from analyzing classroom videos, look at them more than once. Studying transcripts is a powerful way of revisiting a lesson clip. Let go of your everyday *entertainment view* of video watching ("I've already seen that movie") and adopt an *analysis view*.

### *Analysis Basic 4: Consider Alternative Explanations and Teaching Strategies*

A final key step in video-based lesson analysis is setting aside your first reaction and refining or modifying quick judgments. Turn your reaction or initial judgment into a question and then consider alternative explanations for what you're observing. For example:

- **Initial judgment:** *It bothers me that the teacher never answers students' questions. The students must be frustrated.*
- **Questions:** *Why doesn't she answer students' questions? Does this frustrate them?*
- **Alternative explanation:** *The teacher will answer their questions eventually, but for now she just wants students to see the wide range of ideas they have.*
- **Alternative explanation:** *The teacher wants students to answer their own questions and become more active in taking responsibility for their own learning.*
- **Alternative explanation:** *The students are used to this process, so it doesn't frustrate them. They know the teacher values their questions.*
- **Alternative teaching strategy:** *To show that students' questions are valued, the teacher could record them on a class chart or in a class question notebook.*

**Learning from Lesson Analysis**



## Analysis of Student Thinking

| Lesson Analysis Stage | Example |
|---|---|
| **Observation**<br>Begin with an observation, question, or judgment. | • Do the students really understand this activity? |
| **Claim**<br>Turn your observation, question, or judgment into a specific claim. | • I don't think students understand that this activity is intended to demonstrate that water vapor is in the air even though they can't see it. |
| **Evidence and Reasoning**<br>Provide specific evidence and reason(s) why it supports or develops the claim. | • When Maria breathed on the cool mirror and saw the water droplets form, she said, "I can see my breath on the mirror!" (video segment 14:34). Another student in her group said, "We have to use science words to describe what we see." Maria said, "Oh yeah, the science word is *water vapor*." I think she was linking the term *water vapor* to the droplets of water she saw on the mirror. |
| **Alternatives**<br>Consider alternative explanations and teaching strategies. | • A probe question would clarify whether Maria was labeling the droplets themselves as water vapor or thought that her breath contained water vapor as it came out of her mouth. |

## Analysis of Science Content Storyline

| Lesson Analysis Stage | Example |
|---|---|
| **Observation**<br>Begin with an observation, question, or judgment. | • I think students are confused about why they're doing this simulation. |
| **Claim**<br>Turn your observation, question, or judgment into a specific claim. | • The activity setup didn't communicate to students why they would be counting the linking cubes during the simulation role-play. |
| **Evidence and Reasoning**<br>Provide specific evidence and reason(s) why it supports or develops the claim. | • During the activity setup (video segments 15:25–17:20), the teacher described the purpose of the activity as "seeing what happens when matter moves from organism to organism in a food chain." This matches the focus question (*What happens to matter as it moves from organism to organism in a food chain?*). While the activity did address the focus question, counting the linking cubes addressed a different question: *Does any of the matter disappear or get used up?* Students weren't introduced to that purpose of the activity. They just seemed to be doing the math but not thinking about why. It would have been helpful if the teacher had asked, "Why are we counting the cubes?" |
| **Alternatives**<br>Consider alternative explanations or teaching strategies. | • The focus question needed to include something about conservation of matter, which is part of the main learning goal. An alternative might be, *What happens to matter as it moves from organism to organism in a food chain, and does it get used up?* Or maybe it's too much to address both parts of this question in one lesson. |

## Student Ideas and Science Ideas Defined

### Student Ideas

Students don't come to science classrooms as blank slates. Based on their experiences, observations, and learning about the world they live in, they bring to the table many ideas about how to explain events (phenomena) in the world around them. Their ideas are often different from the ideas scientists have developed over centuries of research. Because of this, we sometimes refer to student ideas as "common student ideas," "misconceptions," or "naive theories." These descriptions highlight the fact that their ideas often don't match scientific ideas. But this is not to say that students' ideas are wrong and should be ignored, discounted, or replaced. Quite the contrary. If we listen carefully to their ideas, we discover that their thinking makes a lot of sense based on the evidence available to them. We can find important nuggets of scientific truth in their thinking. To help students build on and change their ideas about the world around them, we should look for the logic in their ideas and think about how they developed those ideas. Then we can plan experiences and provide evidence that will challenge them to deepen their thinking or reconsider their ideas. In STeLLA, we use the phrase *student ideas* to acknowledge their importance and value in shaping our planning and teaching of science. However, student ideas are not necessarily the same thing as science ideas.

### Science Ideas

In STeLLA, we use the term *science ideas* in a very particular way.

| |
|---|
| A **science idea** is a complete sentence (or more) describing scientific knowledge that a student can learn. Think of it as a knowledge outcome in a lesson. A science idea is consistent with knowledge that is agreed upon as part of the scientific-knowledge base that is well supported by evidence. |

A science idea is **NOT**
- a topic (water cycle, food webs),
- a student activity ("Students are making concept maps about states of matter in the water cycle."),
- a set of instructions,
- a question, or
- an interesting student idea that is not scientifically accurate.

In planning and teaching science, it's important to state science ideas in complete sentences to clarify exactly what it is we want students to understand, and how science ideas are different from common student ideas. If we say that our goal is to help students understand uneven heating on Earth (a topic), we aren't clarifying the difference between what students think about water in their world and what scientists have learned about how water changes and is conserved in the water cycle.

There are many different kinds of science ideas. Science ideas can be stated as facts, terminology, descriptions of observations, explanations of phenomena, concepts, patterns, laws, principles, or theories the scientific community accepts as established ways to describe natural phenomena (often referred to as *canonical knowledge*). Following are some examples of science ideas that range from simple facts to concepts and theoretical ideas.

**Examples of Science Ideas about Matter, Molecules, and the Water Cycle**

a. The process of liquid water changing to a gaseous form is called *evaporation*. (*Fact*)

b. When liquid water is heated, it changes more quickly into a gaseous form (evaporates). (*Accurate statement and observable pattern*)

c. In the water cycle, water changes forms, but it never disappears—it's always conserved. (*Concept*)

d. Evaporation and condensation—and other phase changes—can be explained using a model of matter as tiny particles in constant motion. Particle motion increases as heat energy is added and decreases as heat energy decreases. (*Theory*)

**Examples of Science Ideas about Food Webs**

a. Mold and bacteria are decomposers. (*Fact*)

b. In a food chain, rabbits eat grass, and coyotes eat rabbits. (*Description of observations*)

c. *Claim:* Dead logs are broken down into tiny pieces as decomposers like mold, fungi, and bacteria eat them. These tiny pieces eventually become part of the soil. *Evidence:* Our evidence is that we observed pieces of an old log crumbling and breaking off easily. In addition, we saw mold growing on the log. *Reasoning:* We know from our reading research that the mold is eating the log, using its energy and matter to live and grow, and leaving behind tiny particles of matter that become part of the soil. Therefore, we think that the mold growing on the log is breaking it down and making it crumbly. (*Explanation*)

d. Food webs represent how energy flows and how matter cycles through the environment. (*Concept*)

## Strategies to Reveal, Support, and Challenge Student Thinking

## Defining the STeLLA Student Thinking Lens

A major role for you as a teacher is to elicit student ideas and guide their thinking. To continuously diagnose and assess your students' understandings and confusion, you need to use teaching strategies that will make your student thinking visible to you. This means encouraging students to communicate about new ideas as much as possible and helping them elaborate on their ideas by speaking and writing in complete sentences or even paragraphs. You can elicit student thinking when you lead whole-class discussions or engage with individual students or small groups as they work on activities independently. Student thinking can also be revealed to you through their writings, drawings, presentations, and hands-on work with science materials.

Once student thinking is made visible, you need to listen and be on the lookout for misunderstandings, misconceptions, or naive theories just as actively as you look for right answers. Go beyond identifying "wrong" answers and focus instead on figuring out how students' ways of thinking and sensemaking are leading them astray. Diagnosing these misunderstandings is the first step toward supporting students in the challenging process of changing their misconceptions and developing more-scientific explanations of the world around them.

Through the Student Thinking Lens, you'll learn the importance of students' ideas and how to reveal, support, and challenge student thinking. STeLLA presents eight specific strategies teachers can use to focus on student thinking:

1. Ask questions to elicit student ideas and predictions.
2. Ask questions to probe student ideas and predictions.
3. Ask questions to challenge student thinking.
4. Engage students in analyzing and interpreting data and observations.
5. Engage students in constructing explanations and arguments.
6. Engage students in using and applying new science ideas in a variety of ways and contexts.
7. Engage students in making connections by synthesizing and summarizing key science ideas.
8. Engage students in communicating in scientific ways.

Each of these strategies supports teachers in revealing, supporting, and challenging students' scientific thinking:

- Strategies 1–3 focus on particular types of *questions* teachers can ask that help students learn to think and reason scientifically and develop understandings of core ideas and crosscutting concepts in science.
- Strategies 4–7 reveal, support, and challenge student thinking by engaging them in four types of *activities* that are especially important in learning science.
- Strategy 8 helps teachers instruct students explicitly about how to think and communicate like scientists. This strategy engages students in learning to use the eight scientific *practices* identified in the *Next Generation Science Standards* (NGSS Lead States, 2013).

## Strategies to Reveal, Support, and Challenge Student Thinking

## STeLLA Strategy 1: Ask Questions to Elicit Student Ideas and Predictions

Questions and activities reveal student thinking by eliciting prior knowledge, experiences, and predictions relevant to the learning goal. Before studying about food webs or the ways that water changes and moves in the world around us, how are students already thinking about the occasions in their daily lives when they encounter plants and animals interacting or water changing states? What are their personal theories about how plants get their food, how clouds form, and whether the world will run out of water? How do they predict what will happen to once-living matter when it decomposes?

A question or activity designed to elicit students' initial ideas and predictions is addressed to multiple students (the whole class or a small group) and results in a variety of student ideas rather than one "right" answer. The goal of these questions and activities is to learn about students' prior knowledge, misconceptions, experiences, and ways of making sense—whether or not their ideas are scientifically accurate. The more you can understand how students think about phenomena and science ideas, the better you can adapt your instruction in future lessons to challenge their misconceptions and support them in changing their ideas toward more-scientific, evidence-based understandings.

Questions that elicit student thinking also play a role in engaging students in the topic of study—helping them see the links between their own ideas and the science ideas they will learn in the lesson. Students are also able to see that different people have different ideas. This sets up a need to find out which ideas are best.

Predictions can often be used effectively to elicit students' initial ideas. You'll want to take note of these ideas, since they can later be challenged by using a "discrepant event." A *discrepant event* is an observation or piece of information that doesn't match student predictions. For example, students may predict that seeds won't grow in the dark. Observing seeds germinating in the dark is a discrepant event that challenges students to rethink their ideas. You'll learn more about questions that challenge student thinking when you study STeLLA Student Thinking Lens strategy 3.

Questions that elicit student ideas should be phrased in everyday language that will make sense to students even before they begin a unit of study. If a teacher asks, "What do you think photosynthesis is?" most students will have nothing to contribute. In contrast, many students will be able to respond to a question that asks, "How do you think this plant gets its food?" It's best to avoid using scientific terminology when eliciting student ideas. Instead, think of an everyday connection and everyday words that students can explore.

### When Is Strategy 1 Used?

- When a new idea is going to be introduced (often at the beginning of a unit or lesson)
- To set up a discrepant event at any point in the unit of study

### Response to Student Ideas

- Make it clear that you aren't going to tell students which ideas are right or wrong at this point. Confusion may result if students are unclear about which of their peers' ideas are "right" from a scientific perspective, and which are just interesting, so make sure to give your reasons for taking this approach. For example, you might say,

  - "Right now we're just getting our ideas out there. These are just our predictions about ______. Later, we'll gather some evidence to see if we can support or challenge any of our predictions."
  - "As you listen to different ideas, think about which ideas you agree or disagree with. Also think about your reasons for agreeing or disagreeing. Do you have evidence to support your idea? Do you have evidence to challenge someone else's idea?"
- Ask questions to gain more understanding of how students are thinking.
- Ask questions to help students better understand their own thinking.
- Ask questions to help students better understand each other's ideas.

**Examples of Questions That Elicit a Variety of Student Ideas**

***About Matter, Molecules, and the Water Cycle***

- What do you think causes dew to form on the grass?
- Why do you think a mirror sometimes gets foggy after you take a hot shower? Where does that moisture come from?
- After it rains, we sometimes have big puddles on our playground. Later, those puddles are gone. Where did the water go?
- Examine this beaker of boiling water. What do you observe? How do you explain what's happening to make the bubbles in the water? How do you explain what's happening to make the steam?

***About Food Webs***

- How do you think plants get their food?
- If a squirrel dies in the forest and another animal doesn't eat it, what eventually happens to its body? How does that happen?
- How does a tiny seed turn into a huge tree?
- How does a puppy grow into a big dog?
- What happens to all the dead leaves that fall off the trees in a forest?
- Do we need the Sun to get our food? Why or why not?
- What happens to the food that an animal eats?
- Where does a bird get the energy to fly?

## Strategies to Reveal, Support, and Challenge Student Thinking

## STeLLA Strategy 2:
## Ask Questions to Probe Student Ideas and Predictions

Throughout a lesson, you, as the teacher, should take every opportunity to ask questions that probe student thinking. Probe questions are directed to one student who has already provided an answer or offered an idea. The teacher then follows up with this student to probe his or her thinking. Sometimes a teacher asks a sequence of questions that probe one student's thinking before moving on to another student or another thread or topic. These questions shouldn't introduce new language or science ideas, nor are they intended to change student thinking; rather, the goal is to build on ideas a student has already presented. Probing an individual student's thinking can take place during a whole-class discussion or as students work individually or in small groups.

The purpose of asking questions that probe student thinking is to get more information about a student's understanding of an idea he or she has expressed. It isn't designed to teach new ideas or "lead" students to a correct answer.

A probe question may ask a student to provide more information ("Tell me more.") or clarify his or her thinking ("Did you mean …?"). Like questions that elicit student ideas, questions that probe student thinking can help you learn about students' prior knowledge, misconceptions, experiences, and ways of making sense. The more you can understand how students are thinking about science ideas and phenomena, the better you can adapt your instruction to challenge their misconceptions and support them in changing their ideas toward more-scientific, evidence-based understandings. You have to know what students are thinking in order to challenge and guide their thinking effectively!

Questions that probe student thinking are useful for students as well. When asked questions that probe their thinking, students explore, share, and clarify their own ideas. They also benefit from listening to other students' ideas. Just as you want students to listen to each other's responses when you ask elicit questions, you also want them to listen for ideas they agree or disagree with when you're asking another student a probe question. This gives all students an opportunity to consider ideas, evidence, and reasoning that might challenge their thinking.

### When Is Strategy 2 Used?

- After a question designed to elicit student ideas and predictions
- As a follow-up after a question designed to challenge student thinking
- Frequently throughout the lesson

### Examples of General Questions That Probe Student Thinking

- Can you tell us more about that?
- What do you mean when you say …?
- Can you tell me more about how you think that happens?
- So you're saying [paraphrase student response]. Can you tell me how I'm getting it wrong?
- Can you tell me how you're thinking about that?

- Can you put that idea into a complete sentence?

**Examples of Content-Specific Questions That Probe Student Thinking**

***About Matter, Molecules, and the Water Cycle***

T: What do you predict will happen to this dish of water if we let it sit in our classroom for a long time? *(Elicit)*

S: I think the water will disappear.

T: What do you mean by “disappear”? *(Probe)*

S: The water will no longer be in the dish.

T: So do you mean that the water will no longer exist? *(Probe)*

S: Well, it won’t be in the dish anymore.

T: So do you think it will be somewhere else? *(Probe)*

S: Maybe it will go into the clouds.

T: How might it do that? *(Challenge)*

***About Food Webs***

*Context:* The teacher and students are looking at an aquarium that contains plants and fish.

T: What do you predict will happen to this plant if it dies? (*Elicit*)

S: It’ll fall to the bottom, and it might turn into soil.

T: Tell me more about that. (*Probe*)

S: The dead plant would decay.

T: What do you mean by “decay”? (*Probe*)

S: It means that the plant will become rotten and then turn into soil.

T: So you’re saying that dead plants turn into soil? (*Probe*)

S: Yes, the dead plant would decay and turn into soil.

## Strategies to Reveal, Support, and Challenge Student Thinking

### STeLLA Strategy 3:
### Ask Questions to Challenge Student Thinking

Throughout the lesson, you, as the teacher, should take every opportunity to ask questions that probe and challenge student thinking. Probe questions reveal how students are thinking without trying to change their understandings or ideas. In contrast, challenge questions try to move students toward changing their thinking and developing deeper understandings of science ideas. Thus, challenge questions are designed to push students to think more deeply, to reconsider their thinking, to make a new connection, and/or to use new science vocabulary.

Learning to ask good challenge questions takes time and conscious effort. The goal is to get students thinking harder while also scaffolding or guiding their thinking toward more-scientific understandings.

Care must be taken to avoid questions or hints that lead students to the "right" answer without challenging them to really think. Such leading questions are often posed in a fill-in-the-blank or yes-no format, accompanied with hints that frequently enable students to guess the right answer.

| **Examples of Leading Questions to Avoid** | |
|---|---|
| **About Matter, Molecules, and the Water Cycle** | **About Food Webs** |
| T: What happens to puddles when the Sun shines on them?<br>S: They dry up.<br>T: Yes, but what is that process called?<br>S: Uhhhhhh …<br>T: We just wrote that word on the board …<br>S: Oh! Evaporation. | T: What happens to energy in a food web?<br>S: It gets eaten<br>T: But does it get recycled?<br>S: Yes.<br>T: It does?<br>S: I mean no. |

Questions that challenge student thinking don't ask students to simply state a vocabulary term; rather they push students to use science ideas in a meaningful way. Challenge questions avoid leading directly to the right answer and focus instead on guiding student thinking toward a new concept or deeper understanding. It's not an easy task for us as teachers to shift our focus from helping students get the right answers ("leading") to challenging students to develop or clarify their thinking and reasoning.

**When Is Strategy 3 Used?**

- Anytime during the lesson *except* when you're trying to elicit students' initial ideas and predictions about a science idea or concept

**Examples of General Questions That Challenge Student Thinking**

- Can you add some of the new ideas we've been talking about to your explanation?

- Can you explain how that happens?
- Why does that happen?
- How does that relate to the ideas we've been studying?

**Examples of Content-Specific Questions That Challenge Student Thinking**

***About Matter, Molecules, and the Water Cycle***

T: What are clouds made of?

S: They're made of drops of water.

T: When you say "drops of water," what do you mean? (*Probe*)

S: I mean liquid-water drops.

T: OK, liquid-water drops. How did those drops of water get there? (*Challenge*)

S: Evaporation.

T: Put that in a complete sentence to tell me what you mean by evaporation. (*Probe*)

S: Water evaporated, like from a lake, and went up into the air and into the clouds.

T: But how does that happen? How can water go up into the air? (*Challenge*)

S: Evaporation is when liquid-water molecules float up into the air and make clouds.

T: So you're saying that evaporation is when liquid-water molecules float up into the air and make clouds. Is that right? (*Probe*)

S: Yes, they go up into the air.

T: What state of matter is the water in when it's floating in the air? (*Challenge*)

S: It's water vapor.

T: OK. It's water vapor. What do you know about water vapor? (*Probe*)

S: It's in the air all the time. It's a gas.

T: Can you see water vapor?

S: No.

T: Why can't we see the water-vapor molecules floating in the air? (*Challenge*)

S: Well, maybe you can't see them until they get high up in the sky where it's colder and there's less oxygen.

***About Food Webs***

T: When you look at our forest food web, what can you say about the connection between the bird and the snake?

S1: The snake eats the bird.

T: Tell me more about that. (*Probe*)

S1: Well, the bird is food for the snake.

T: Why do you think the arrow points from the bird toward the snake? (*Challenge*)

S1: The arrow shows the bird giving energy to the snake when the snake eats it.

T: Where did that energy come from? (*Challenge*)

S1: Well, it came from the bird.

T: How did the bird get the energy? (*Challenge*)

S: From the food it ate—like seeds and worms.

T: Where did the seeds and worms get the energy? (*Challenge*)

S1: I don't know.

S2: All the energy originally came from the Sun, which the producers used to make food.

T: OK, so you're saying that energy originally came from the Sun? (*Probe*)

S2: Yes.

T: What will happen to the energy that the snake gets from eating the bird? (*Challenge*)

S3: The energy gets passed on when the snake is eaten by the hawk [bird].

S4: I disagree. Not all of the energy gets passed on; just some.

T: Who agrees or disagrees? Does the snake pass on all of the energy to the hawk [bird], or just some? Be ready to give a reason for your answer. (*Challenge*)

S5: The snake uses some of the energy to live and grow, so only some can be passed on to the hawk [bird].

T: So [S1] said that the arrows show how energy moves from the bird to the snake. Are there other things that the arrows might show or represent? (*Challenge/Elicit*)

S6: The arrows can show how food moves from the bird to the snake.

S7: The arrows can show how matter moves from the bird to the snake.

S8: The arrows show how food molecules move from the bird to the snake.

S7: The arrows can show how matter *and* energy move from the bird to the snake.

## Strategies to Reveal, Support, and Challenge Student Thinking

## STeLLA Strategy 4:
## Engage Students in Analyzing and Interpreting Data and Observations

**Overview of Student Thinking Lens Strategies 4–7**

Strategies 1–3 focus on types of *questions* teachers can ask to reveal and challenge student thinking. Strategies 4–7 focus on four types of *activities* that can reveal and challenge student thinking:

- Engage students in analyzing and interpreting data and observations.
- Engage students in constructing explanations and arguments.
- Engage students in using and applying new ideas in a variety of ways and contexts.
- Engage students in making connections by synthesizing and summarizing key science ideas.

In each of these types of activities, students should be asked questions that probe and challenge their thinking.

We'll focus now on what it means to engage students in analyzing and interpreting data and observations.

*Analyzing and interpreting data* is one of eight scientific practices identified in the *Next Generation Science Standards* (NGSS Lead States, 2013) as essential in elementary science classrooms. This practice is important because observations and raw data have little meaning on their own. But when they are organized and represented in a variety of ways, the result reveals or communicates different aspects of the data. In some instances, students record data in a table as they collect it, but they need to graph the data to reveal a pattern. In other instances, students need to observe a physical representation of a natural phenomenon or draw pictures of what they see to make sense of something in their world.

When students *organize* data, they may construct tables, graphs, or diagrams. When they *analyze* data, they identify patterns, find similarities and differences, or use statistical analysis, such as finding an average (i.e., a mean, median, or mode). When students *interpret* data, they bring meaning to the patterns they identify and find relationships using science ideas and knowledge/data in their experiences. They connect observations or patterns to science ideas or use data and observations to answer a question. Analysis and interpretation bring out the meaning of data—and their relevance—so that students can use it as evidence to construct an explanation or engage in argumentation.

Students need support in learning how to organize, present, and analyze data in ways that will reveal patterns and relationships. As with analysis and interpretation, patterns also help students make sense of data and observations so they can use this information as evidence in constructing explanations of phenomena.

How can you help students learn to *organize* data and observations?

- Make sure students can distinguish between an observation and an interpretation or idea about what the observation might tell them about how the world works.

- Help students record their data and observations accurately using words, drawings, numbers, or combinations of these.
- Provide feedback to help students communicate their observations clearly and completely. Some teachers require students to speak and write in complete sentences whenever they share their observations and ideas.

How can you help students learn to *analyze and interpret* data and observations?

- Encourage students to look for patterns in their data and observations.
- Teach students how to find patterns by organizing and presenting data and observations in forms that will help them see this information in new ways. It's important to teach students how to create and interpret these different forms, emphasizing how they can help reveal patterns in data. These forms include the following:
  - Drawings
  - Charts
  - Tables
  - Diagrams
  - Venn diagrams
  - Different kinds of graphs
- Have students share data and observations with the class to identify patterns. This allows students to draw on a larger set of data and observations from which clear patterns and trends, as well as exceptions in the data, may become more visible.
- Computers, digital tools (e.g., sensors, animations, databases, and spreadsheets), and mathematics can sometimes help students see patterns that will support their analyses and interpretation of data. But don't use these tools just because they're "cool." Make sure they'll help students develop richer scientific understandings of the learning goals. When deciding whether to use these tools, ask yourself the following questions:
  - Do these tools support students in collecting and/or making meaning of their data in age-appropriate ways that are consistent with the lesson's science content storyline?
  - Are these tools interesting and engaging but potentially distracting from the storyline and intended learning?

**When Is Strategy 4 Used?**

- Anytime during the lesson when students are investigating phenomena and/or scientific models
- To help develop student understandings of new science ideas
- As an opportunity for students to apply new science ideas in order to make sense of a new set of data or observations
- When students are learning to communicate in scientific ways (See Student Thinking Lens strategy 8: Engage students in communicating in scientific ways.)

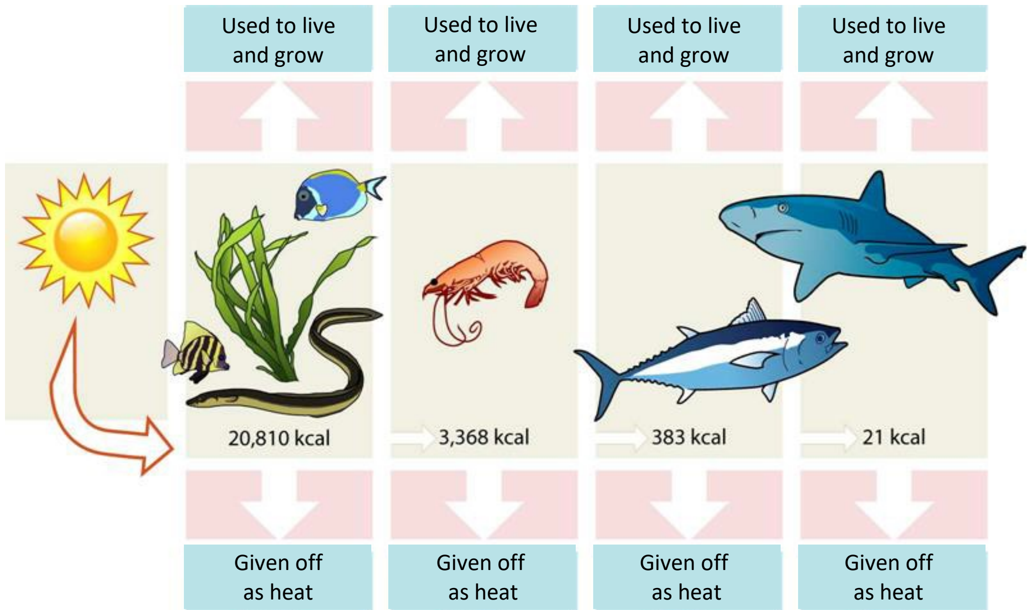
## Examples of Analyzing and Interpreting Data and Observations

### *About Matter, Molecules, and the Water Cycle*

- Students observe a glass of room-temperature water and a glass of ice water. Then they draw pictures to show the pattern of water droplets forming on either of the glasses.
- Students draw diagrams showing what they observe when a beaker of water is heated on a hot plate, and they label the liquid and gaseous states of water.
- Students use an animation showing the behavior of water molecules in different states of matter to gather descriptive data about how the motion and arrangement of water molecules is different in solid, liquid, and gaseous states.
- Students weigh three bottles that contain equal amounts of water. One bottle is then put in the freezer, one is left out at room temperature, and one is heated to cause evaporation within the bottle. After a period of time, students weigh the bottles again and analyze the data to determine the patterns of change. They then interpret the data to make a generalization about changes in mass during phase changes of water.
- Students use an online simulator to record numeric data about the speed of water molecules at different temperatures. Then they graph the data, showing that the speed of water molecules increases as temperature increases.

### *About Food Webs*

- Students write about their observations of one clear glass jar containing decomposing matter. Then they look for patterns across several jars containing different kinds of decomposing matter.
- Students measure and record the height of food matter that is left to sit in a clear glass jar undisturbed for 10 days. They measure and record the height of the food matter on days 1, 5, and 10. They also measure and record the height of liquid in the base of the jar on these three dates. Students then graph the data, showing that the height of the liquid increases as the height of food matter decreases.
- Students record the amount of matter (grams) and the amount of food energy (Calories) contained in different grocery-store products (e.g., milk, water, potato chips, vitamins) and use these data to identify two types of materials—materials that have both mass and food energy ("food"), and materials that have mass but no food energy ("not food").
- Students analyze the following diagram to identify the pattern of energy flow in the food chain by computing the percentage of energy, or kilocalories (kcal), passed from producers to herbivores, from herbivores to small carnivores, and from small carnivores to large carnivores.


Used to live and grow
Used to live and grow
Used to live and grow
Used to live and grow
20,810 kcal
3,368 kcal
383 kcal
21 kcal
Given off as heat
Given off as heat
Given off as heat
Given off as heat

## Strategies to Reveal, Support, and Challenge Student Thinking

## STeLLA Strategy 5:
## Engage Students in Constructing Explanations and Arguments

The job of a scientist is to come up with ideas that help explain aspects of the world, such as why the Sun rises in the east, why tides rise and fall in a predictable pattern, and why we are similar—but not identical—to our parents. Likewise, students studying science should learn to construct scientific explanations to help them make sense of their world. As students construct explanations, they

- deepen their understandings of important science ideas;
- create an account of *why* events happen, not merely descriptions of *what* happened;
- speculate about things they cannot directly observe (things that are too small, like atoms; too slow, like mountain building; too quick, like electricity moving through a circuit; or too abstract, like gravity); and
- use evidence from data and observations to create logical reasons that support their ideas.

Arguments in science play an important role in this explanation-building process. Scientific arguments aren't the same as arguments in everyday situations. In science, arguments are conversations used to justify and support new ideas and address questions about the design of experiments and the interpretation of data. Through argumentation, scientists question one another with the goal of coming to a shared understanding that is plausible and supported by evidence—not merely to convince each other that they are right. As students engage in scientific argumentation, they also engage in classroom conversations to

- justify and defend explanations using evidence and logical reasoning,
- compare competing explanations,
- evaluate the way an experiment was designed or how data was interpreted to identify weaknesses and limitations of proposed explanations, and
- determine whether proposed explanations fit the data and are reasonable based on other experiences in the world.

Explanation and argumentation depend on each other in science. Students engage in argumentation as they work to construct, defend, and evaluate explanations of various phenomena or events. In this discussion, we'll consider each practice separately and then provide some classroom examples to demonstrate how they work together to help students deepen their understandings of science ideas.

### Constructing Explanations

*Constructing explanations* is one of the eight essential science practices for K–12 science education defined in the *Next Generation Science Standards* (NGSS Lead States, 2013). Scientific explanations create a storyline of *why* observable events happen. They're often used to predict future events or make inferences about past events. However, scientific explanations aren't storylines that emerge from our imaginations. They are logical, supported by data and observations, and link new ideas to established scientific concepts.

A description of one student's experience in science class might help you better understand scientific explanations. Rachel was a 5th-grade student in a hands-on science classroom where the class had been growing plants in the light and the dark, making careful observations and measurements over the course of a month. Rachel created beautiful graphs and detailed descriptions of her plants. She was a careful observer. But at the end of the unit, she was frustrated: "It was fun at first. But I always knew plants needed light and now I know it again." All that measuring and observing didn't lead her to any new understandings about plants. The entire activity led her to a description about *what* happened without any new understanding of *why* it happened.

Generating explanations involves *logical thinking*, using *science ideas* to make sense of *evidence* in the form of observations and data:

| Constructing explanations = Logical thinking + Science ideas/theories + Evidence |
|---|

How can we best help students engage in reasoning to construct and understand scientific explanations? To support this kind of work, an atmosphere needs to be created that welcomes students' genuine ideas and their efforts to build explanations from evidence rather than the more typical search for what the teacher wants to hear.

A useful framework for guiding students in their construction of explanations was developed in the *Investigating and Questioning Our World through Science and Technology* curriculum (Krajcik & Reiser, 2004), which emphasizes three aspects of constructing scientific explanations: claim, evidence, and reasoning (CER). We have modified this framework to emphasize the central role of science ideas in scientific reasoning and clarify what is involved. Following is a description of each step using language from Krajcik and Reiser, as well as our added language (in italics).

- **Claim:** What happened, and why do you think it happened? A claim is a statement that answers a question we are investigating.
- **Evidence:** What information or data or observations support your claim?
- **Reasoning:** *How can you use **logic** and **science ideas** to explain the evidence and support your claim? What science ideas (theories) can you use to help make sense of this evidence? How can you use linking words to help you connect your claim, evidence, and reasoning?*

As students use the claim, evidence, and reasoning framework, they learn how to build explanations by thinking through the science ideas and evidence.

### Constructing Arguments[1]

Scientists work hard to set aside their beliefs and biases and focus instead on what they actually see in their data and observations. But this isn't always easy because different explanations can be given for the same evidence. Consequently, scientists must critically evaluate the logic of the reasoning as well as the evidence used in building any explanation. Scientists present arguments to make the case for their proposed explanations. In response, other scientists use arguments to identify a claim's weaknesses and limitations. Argumentation is also needed to resolve questions involving the best experimental design, the most appropriate techniques of data analysis, or the best interpretation of a data set.

[1]This section draws heavily from *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas* (pp. 71–74) by the National Research Council (NRC), 2012, Washington, DC: National Academies Press.

Even very young students can begin constructing their own arguments to explain data and observations. But the teacher needs to support students by creating conditions where they actively listen and respond to one another, as well as a classroom culture that encourages them to make sense of events and phenomena rather than merely restating ideas from a textbook or the teacher. STeLLA Student Thinking Lens strategy 8—Engage students in communicating in scientific ways—provides language you can use to introduce students to the argumentation process:

- Think of an idea, claim, and explanation.
- Give a reason or evidence for your idea.
- Listen to others' ideas and ask clarifying questions, agree or disagree with others' ideas, or add onto someone else's idea.
- Suggest an experiment or activity to get more evidence.
- Let your ideas grow and change.

In addition, strategy 8 provides sentence starters that students can use to support developing their argumentation ability:

- *My idea is …*
- *My evidence is …*
- *I agree/disagree because …*
- *I want to add onto what _______ said.*
- *We could get better evidence if …*
- *I want to change my idea …*

**When Is Strategy 5 Used?**

- Anytime during the lesson when students are reasoning about observations and other forms of data, communicating to reach a common understanding of the science content storyline, and making links between their observations and science ideas.

**Examples of Constructing Explanations and Engaging in Scientific Argument**

***About Matter, Molecules, and the Water Cycle***

*Example 1*

*Context:* Students observe water droplets form on the outside of a glass of cold water to which food coloring has been added to make the water red.

T: Do you have an explanation for why there are water droplets on the *outside* of this glass?

S1: Some of the water in the glass evaporated into the air as water vapor, and then when it got near the cold glass, it turned back into liquid water because it got cooled down.

S2: But the water in the glass is red, and the water on the outside of the glass isn't red. So I don't think the water on the outside of the glass could have come from inside the glass.

S3: I agree. I think the water on the outside of the glass must have come from the air because water-vapor molecules in the air aren't red, but the water molecules in the glass seem to be red. When the molecules in the air get near the cold glass, they start slowing down and clumping together to form liquid-water drops.

*Example 2*

T: So we have two ideas about how clouds form. Wyatt says that clouds form when water evaporates from Earth and goes up into the sky as water vapor. Does anyone have a question for Wyatt about his idea?

Angela: Are you saying the clouds are water vapor?

Wyatt: Yes.

Angela: Then why do they suddenly look white up high in the sky, but down low, you can't see them?

Wyatt: Because I've heard there's dust high in the sky, so actually it's the dust that looks white. We learned that you can't see water vapor.

T: OK, now let's consider Maria's idea. What's your idea, Maria?

Maria: I think clouds are made of liquid-water droplets that form on the dust particles that are in the sky.

T: Does anyone have any questions about this idea?

Steven: How do the water droplets get there?

Maria: Water evaporates from Earth, and when it gets high up, it cools off, and the water molecules come together to make liquid, just like when we saw water drops form on the glass of ice water.

T: Does anyone have any evidence to challenge either of these ideas?

Dawn: Well, we saw that steam coming out of a teapot is made of liquid drops. And I think clouds look kind of like steam, so I think Maria is right.

Marco: I've flown through a cloud in an airplane, and the window got wet. Just like when we put the scissors in the teapot steam, and they got wet.

***About Food Webs***

*Example 1*

*Context*: Students are looking at a classroom terrarium that has remained covered since the day it was created, and they see some "white stuff" on the bottom of the terrarium that wasn't there at the beginning. They've learned about producers, consumers, and decomposers and their roles in a food web.

T: Many of you have commented that there is now white stuff in our terrarium, and that there is more of it today than there was last week. Where do you think the white stuff might have come from, and what do you think it might be?

S1: We thought that maybe someone put something into the terrarium, but we didn't see evidence that the seal of the terrarium was broken.

S2: The seal is still OK. I don't think anyone could have added anything.

T: Any other ideas?

S3: Maybe it came from one of the crickets. Like poop or something. It kinda looks like bird poop.

T: Do you have any evidence to support that idea?

S3: Not really. We haven't actually seen the crickets poop. But we did look on the Internet and found out that insects do poop. We saw a video of a ladybug pooping!

S4: But the poop wasn't white.

T: Other ideas about the white stuff?

S5: Well, we think it's alive because it seems to be growing bigger.

S6: It looks kind of like mold, and I think mold grows because I've seen mold growing on bread and other old stuff in the refrigerator. So we thought it was mold growing and eating the bread.

S7: I disagree about mold eating the bread. I think it grows, but it's not alive because, well, it grows on old stuff, but I don't think it's like eating that stuff. It just grows on it. Like that's just what happens when things get old. The white stuff doesn't look like it's alive.

S6: But if it's not alive, how can it grow? I don't think nonliving things can grow.

S7: What about those magic animal figures? They're not alive, but if you put them in water, they grow really big. They don't grow by eating. They grow by soaking up water.

T: For those of you who think the white stuff is alive, do you think it needs food?

S6: Yes. I think it might be eating the grass and leaves on the floor of the terrarium.

T: Do you have any evidence to support that idea?

S6: Well, the white stuff is sitting on some leaves at the bottom of the terrarium, and it's not sitting in other places.

T: Any other ideas about what is going on here?

S7: I think maybe the white stuff is a decomposer. Because it's growing on dead leaves, and dead leaves eventually get broken down into little pieces, and maybe the white stuff is making that happen.

S8: But I don't see the leaves in our terrarium getting broken into little pieces.

S7: Maybe it won't happen until the white stuff grows more, because the book we read said that sometimes decomposition takes a very long time.

T: Let's watch the white stuff the rest of the week and describe how it changes and see if we can get any more evidence to support or challenge the idea that the white stuff is alive. If it is alive, can we figure out if it's a decomposer as [S7] suggested?

*Example 2*

T: How do you explain your observations of the rotting log?

Tony: I think that the log is decomposing because I see little pieces are breaking off.

T: Why is it decomposing?

Tony: Because it's getting old.

Mary: I agree that it's decomposing, but I don't think it's because it's old. I think it's decomposing because mold is growing on it.

Chad: I agree with Mary because we learned that mold eats once-living things and breaks them down into little pieces, and there is mold on the log, and I see little pieces forming.

Kiran: I agree with Tony because I think mold only grows on old stuff. Like in your refrigerator, mold only grows on things that have been in there a long time.

T: It sounds like we all agree that the log is decomposing. Does anyone have a different explanation for why it's decomposing?

Dana: I think it's decomposing because it's been out in the rain for a long time, and the rain is breaking it apart and making it soft.

## Strategies to Reveal, Support, and Challenge Student Thinking

## STeLLA Strategy 6:
## Engage Students in Using and Applying New Science Ideas in a Variety of Ways and Contexts

After students encounter new science ideas, they need the opportunity to practice using them and to see their usefulness in explaining a variety of phenomena. Too often, we as teachers expect students to hear a new idea and then immediately understand and be able to use it in a scientifically accurate way. This is one of the most common mistakes in science teaching and learning—we simply don't give students enough opportunity and time to wrestle with new ideas that are often in conflict with their personal ideas and theories. Research shows that the process of meaningful conceptual learning is a messy one in which students often cling to their personally sensible ideas and have difficulty changing their ideas and ways of thinking even after learning about contradictory evidence, scientific explanations, and scientific ways of thinking.

To learn ideas that are often abstract and difficult, students need multiple opportunities to use them in a variety of situations before they really make sense of the ideas and develop a meaningful conceptual understanding. When students are challenged to explain a new real-world situation they haven't encountered before, at first they'll fall back on prior knowledge and misconceptions to explain the situation. Only with practice in explaining a variety of real-world situations, as well as careful support and guidance from the teacher, will they become comfortable and successful using new science ideas to explain new scenarios and phenomena. As students start internalizing new science ideas, they will need less and less guidance and support from others and will develop a deep conceptual understanding they can use to reason about different situations.

Activities that challenge students to use and apply new ideas go beyond asking students to repeat knowledge they've learned or memorized (e.g., "What is evaporation?"). Use-and-apply activities require students to think, reason, and make sense of science ideas to explain new situations. Students must connect the ideas they're learning to new scenarios, situations, or phenomena, and they must make connections among science ideas.

Use-and-apply activities come in different forms, each of which is most effective if it requires students to put at least two ideas together and respond in one or more complete sentences. Following are examples of activities that challenge students to use and apply new ideas:

- Explaining a new situation or phenomenon.
- Making predictions.
- Making sense of new observations or experimental data.
- Creating synthesis diagrams or concept maps.
- Designing a solution to a practical problem.

**Don't Worry!**

As the previous list indicates, sometimes an investigation that engages students in analyzing and interpreting data and observations (strategy 4) can be used as an opportunity for students to use and apply new ideas (strategy 6). As you'll learn shortly, synthesizing and summarizing activities (strategy 7) can also provide opportunities for students to use and apply new ideas.

Don't worry about how to classify a particular activity. Just make sure to be clear about your purpose for an activity. Are you using a firsthand investigation to help students encounter and begin developing a new idea or to give students a chance to practice using new ideas they've already encountered but not yet mastered? The most important thing is this: *Give students many opportunities to think, reason, and explain; make connections; and practice using new ideas in multiple contexts.*

Teachers sometimes pose use-and-apply questions to assess student learning at the end of a unit of study. While such questions make excellent and challenging assessment tasks, don't wait until the end of a unit to pose them. Students need multiple opportunities to practice using new ideas in a variety of contexts in order to *develop* a deep understanding of the concepts. That is, use-and-apply activities are an essential (and often underused) part of the learning process. If students have the opportunity to really make sense of new ideas through a number of different use-and-apply experiences, they will develop understandings that enable them to successfully tackle use-and-apply test questions at the end of the unit or school year.

**When Is Strategy 6 Used?**

- *After* students have encountered new science ideas
- *Before* the final unit assessments

**Examples of Using and Applying New Ideas**

***About Matter, Molecules, and the Water Cycle***

- Work with your group to create a chart showing *how water molecules change in the water cycle*. Use any terms you need to make an accurate drawing, and make sure to label any arrows. Be ready to present your diagram to the class.

  *Note 1:* Students could write a paragraph under the diagram to synthesize and summarize their ideas (strategy 7).

  *Note 2:* This example also engages students in creating a content representation (strategy D of Science Content Storyline Lens strategies).

- We observed condensation on a can of soda. Think with your group about instances in nature where we can observe condensation. For each example, be ready to share how and why you think condensation occurs.

  *Note:* Alternatively, the teacher could present a variety of condensation phenomena to students and have them explain their observations. For example, they could go outside on a cold day and observe their breath. The teacher could challenge them with this question: *Why is your breath visible today?* This would be an example of a use-and-apply activity that also engages students in constructing explanations (strategy 5).

- Sarah wonders why some mornings there is dew on the grass, and other mornings there is no dew. Use what you know about the water cycle and molecules to explain this situation.

  *Note:* Students could be asked to represent their ideas with a content representation, such as a labeled diagram (strategy D).

***About Food Webs***

- Students encounter drawings of a collection of organisms they haven't seen before. Their task is to organize them into a food web that

    - shows how matter moves among the organisms, and
    - shows their understandings of the terms *producer*, *consumer*, and *decomposer*.

- Students have been studying the roles of producers, consumers, and decomposers in food webs. The teacher gives each small group of students a rotting log. The students' task is to describe what is happening in the log in terms of producers, consumers, and decomposers and explain their reasoning.

## Strategies to Reveal, Support, and Challenge Student Thinking

## STeLLA Strategy 7: Engage Students in Making Connections by Synthesizing and Summarizing Key Science Ideas

Many times, the teacher or the textbook does all the organizing and synthesizing of the science content, and the students are simply expected to absorb the information. However, students will be challenged to think and reason and make sense of science ideas if they're given the task of synthesizing and summarizing the ideas, evidence, and experiences they've encountered in lessons or units.

One way to engage students in this work is to ask them to write a summary at the end of the lesson (either individually or in small groups). To support students in constructing meaningful summaries, you can scaffold this work (especially at first) by giving them key words to use in their summaries, requiring them to write a certain number of sentences, or providing a sentence starter, among other possibilities. Whole-class discussion of these student summaries can then be used to highlight key ideas.

Synthesis activities involve teachers and students in pulling together various new ideas—in making connections and synthesizing ideas. In fact, sometimes the entire lesson is focused on a synthesis activity. For example, toward the end of a series of lessons about the water cycle, the teacher might have students work in small groups to create and present a diagram that illustrates how the processes of evaporation, condensation, and precipitation move water between Earth's surface and its atmosphere. Or students might create a concept map that organizes key science ideas about matter cycling in food webs. Making a concept map and presenting it to the class could be the focus of an entire lesson. Such an activity involves students in actively considering how all the ideas they studied fit together.

Synthesis work can take a variety of forms. For example, students could write a unit synthesis of ideas, or they might create visual representations, such as concept maps, diagrams, Venn diagrams, models, charts, or role-plays. A true synthesis task that will make students' understandings (and confusion) visible doesn't simplify the task by allowing students to repeat memorized information. Instead of giving students a diagram to label, for example, the teacher might give them a blank sheet of paper to create their own diagrams and then have them explain their diagrams to others to elaborate the meaning behind them.

### When Is Strategy 7 Used?

- After students have encountered new science ideas and/or observations, usually at the end of a lesson or after a series of lessons on related content.

### Examples of Synthesizing and Summarizing Key Science Ideas

#### *About Matter, Molecules, and the Water Cycle*

- At the end of a series of lessons, the teacher points to science words or phrases that were introduced: *evaporation*, *precipitation*, *condensation*, *adding heat*, *losing heat*, *molecules*, and *water cycle*. Students are asked to use these words in two to three sentences that explain the relationships among them. Each student shares his or her sentences with the class; then classmates and the teacher ask questions and give feedback afterward.
- At the end of a series of lessons about water, molecules, and the water cycle, students

are asked to write a story that tells what happens in the water cycle from the perspective of different "characters": a drop of water, the Sun, a cloud, a water molecule, and a river.

- At the end of the lesson about condensation, students are assigned the following homework questions:
    - Use the following words to explain a real-world example of condensation: *heat energy, water molecules, and water vapor.*
    - Write a question you still have about condensation. What confuses you? What could you learn more about?

***About Food Webs***

- At the end of a lesson, the teacher points to six vocabulary words that were used in the lesson: *producer*, *consumer*, *herbivore*, *carnivore*, *omnivore*, and *decomposer*. Students write two sentences and draw a diagram explaining the relationships among those words. Each student shares his or her sentences and diagrams with the class; then classmates and the teacher ask questions and give feedback afterward.
- At the end of a series of lessons about food webs, the teacher asks students to create a diagram of a food chain that shows a producer, an herbivore, one or two carnivores, and a decomposer. Then students show how matter moves through the food chain by adding arrows, labels, and other words to the diagram. They also write a brief paragraph explaining their diagrams.
- At the end of a series of lessons about matter cycling in food webs, students observe a mini-environment that includes a variety of plants and small organisms. The environment is closed, so no food or water can be added. The only thing that is added to the environment is sunlight. Students are challenged to use what they've learned to answer the question, "Do all the organisms in the mini-environment have what they need to get their food to live? Explain your reasoning."
- At the end of a series of lessons about food webs, students draw a diagram of a food web that includes themselves. Then they answer such questions as "Where would you include humans in a food web? Why did you place humans in this position in the food web? Please use the terms from our unit to explain your answers: *food*, *matter*, *energy*, *carbon dioxide*, *water*, *producer*, *consumer*, and *decomposer*."

## Strategies to Reveal, Support, and Challenge Student Thinking

## STeLLA Strategy 8:
## Engage Students in Communicating in Scientific Ways

Students' thinking will be revealed more clearly as they learn to think and communicate using scientific norms of discourse. In other words, students should learn to think and communicate in scientific ways, though they may not always use scientific terminology. Scientific discourse centers on a particular argumentation pattern that values the use of evidence, coherent reasoning, and consistent explanations with supporting data. Scientists expect skepticism and challenging questions in response to their ideas. Students can adopt such scientific discourse and use it to propose ideas or explanations, support ideas with evidence, ask challenging questions, and agree or disagree with their classmates' ideas.

The National Research Council convened a prestigious panel of expert science-education researchers, teachers, scientists, and cognitive psychologists, who issued a report emphasizing the importance of helping elementary students learn to participate and communicate productively in science (NRC, 2008). Their description of this strand of scientific proficiency highlights the importance of engaging students in

- learning how to communicate effectively in a scientific community in the classroom,
- understanding the norms for presenting scientific arguments and evidence, and
- practicing productive social interactions with peers in the context of classroom science investigations.

The panel concluded that, like scientists, "science students benefit from sharing ideas with peers, building interpretive accounts of data, and working together to discern which accounts are most persuasive" (NRC, 2008, p. 21). However, before they can be effective in this new way of interacting with one another, students need to learn about scientific argumentation and how it differs from arguments more familiar to them, such as those that occur on the playground. Scientific ways of thinking and communicating don't just develop as students engage in science activities; they need to be explicitly taught. Explicitly teaching students about scientific practices and communication will help them better understand the nature of science and improve the clarity, precision, and elaboration of their ideas.

Such explicit instruction about scientific ways of communicating is also essential in addressing the diverse student populations in our schools. While many students learn about scientific ways of thinking at home and in extracurricular activities, some students grow up in cultures and environments where different ways of thinking are highly valued and emphasized; others grow up in more insular environments where expressing differing viewpoints is actively discouraged. These students need to learn about scientific ways of thinking and communicating in order to understand and be successful in a new cultural setting—the scientific community.

The *Next Generation Science Standards* (NGSS Lead States, 2013) represent a national consensus that science education should help K–12 students learn core science ideas and crosscutting concepts through the use of eight essential scientific practices:

1. Asking questions
2. Developing and using models
3. Planning and carrying out investigations

4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

These practices represent a much richer view of scientific activity than the “scientific method,” the widely accepted but overly simplistic view of science. The NGSS science practices present a more accurate view of science as focusing on evidence and argument in building and using models and in generating explanations to make sense of phenomena. The STeLLA strategy of communicating in scientific ways supports students in learning about and using these eight science practices. The purpose of strategy 8 is to help you explicitly teach elementary students how to develop these practices. The following chart shows the relationship between the STeLLA descriptors for communicating in scientific ways and the science practices defined in the NGSS. The STeLLA language is designed to be more accessible to K–12 students.

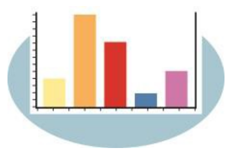
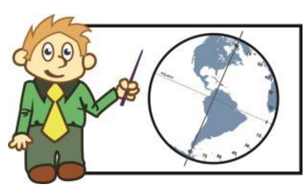
<table>
<tr><th></th><th>STeLLA<br>Communicating in Scientific Ways</th><th>Next Generation Science Standards:<br>Science Practices</th></tr>
<tr><td>1.</td><td>Ask why and how questions.</td><td>Asking questions</td></tr>
<tr><td>2.</td><td>Observe.</td><td rowspan="2">Analyzing and interpreting data<br>Using mathematics and computational thinking</td></tr>
<tr><td>3.</td><td>Organize data and observations.</td></tr>
<tr><td>4.</td><td>Think of an idea, claim, prediction, or model to explain your data and observations.</td><td rowspan="3">Developing and using models<br>Constructing explanations</td></tr>
<tr><td>5.</td><td>Give evidence for your idea or claim.</td></tr>
<tr><td>6.</td><td>Reason from evidence or models to explain your data and observations.</td></tr>
<tr><td>7.</td><td>Listen to others’ ideas and ask clarifying questions.</td><td rowspan="3">Engaging in argument from evidence</td></tr>
<tr><td>8.</td><td>Agree or disagree with others’ ideas.</td></tr>
<tr><td>9.</td><td>Add onto someone else’s idea.</td></tr>
<tr><td>10.</td><td>Search for new ideas from other sources.</td><td rowspan="2">Obtaining, evaluating, and communicating information</td></tr>
<tr><td>11.</td><td>Consider whether new ideas make sense.</td></tr>
<tr><td>12.</td><td>Suggest an experiment or activity to get more evidence or to answer a new question.</td><td>Planning and carrying out investigations</td></tr>
<tr><td>13.</td><td>Let your ideas change and grow.</td><td></td></tr>
</table>

**Examples of Ways to Engage Students in Communicating Scientifically**

The Communicating in Scientific Ways chart on the following pages can be used to teach elementary students about scientific practices and communication. This tool connects what scientists *do* with the kind of talk they use to *communicate about* what they do. When used frequently, this chart can help you support students in improving their abilities to engage in scientific practices and communication.

**STeLLA: Communicating in Scientific Ways**

| What a Scientist Does | Symbol | What a Scientist Says |
|---|---|---|
| 1. Ask why and how questions. |  | How come …?<br>I wonder …<br>Why …?<br>How do they know that …? |
| 2. Observe. |  | I see …<br>I noticed …<br>I recorded …<br>I measured … |
| 3. Organize data and observations. |  | I see a pattern …<br>I think we could make a graph …<br>Let’s make a chart … |
| 4. Think of an idea, claim, prediction, or model to explain your data and observations. |  | My idea is …<br>I think that …<br>We could draw a picture to show …<br>I think it looks like this … |
| 5. Give evidence for your idea or claim. |  | My evidence is …<br>The reason I think that is …<br>I think it’s true because … |
| 6. Reason from evidence or models to explain your data and observations. |  | The reason I think my evidence supports my claim is because …<br>The model shows that … |

| What a Scientist Does | Symbol | What a Scientist Says |
|---|---|---|
| 7. Listen to others' ideas and ask clarifying questions. |  | Are you saying that …?<br>What do you mean when you say …?<br>What is your evidence? |
| 8. Agree or disagree with others' ideas. |  | I agree with _______ because …<br>I disagree with _______ because … |
| 9. Add onto someone else's idea. |  | I want to piggyback on _____'s idea.<br>I want to add onto what _____ said. |
| 10. Search for new ideas from other sources. |  | We could get some new ideas from … |
| 11. Consider whether new ideas make sense. |  | That idea makes sense to me because …<br>That idea doesn't make sense because …<br>What's their evidence? |
| 12. Suggest an experiment or activity to get more evidence or to answer a new question. |  | What if we …?<br>We could get better evidence if we … |
| 13. Let your ideas change and grow. |  | I think I'm changing my idea.<br>I have something to add onto my idea. |

## Summary of STeLLA Student Thinking Lens Strategies

| | Strategy | When | Purpose |
|---|---|---|---|
| **Questions** That Reveal and Challenge Student Thinking | Ask questions to elicit student ideas and predictions. | When a new idea is going to be introduced<br>Before a new learning goal is developed | To reveal students' initial ideas, predictions, misconceptions, and experiences |
| | Ask questions to probe student ideas and predictions. | Anytime | To reveal more about a given student's current thinking |
| | Ask questions to challenge student thinking. | As part of developing the learning goal (not when eliciting students' initial ideas) | To challenge student thinking in the direction of the learning goal<br>To help change student thinking about the science ideas |
| **Activities** That Challenge Student Thinking | Engage students in analyzing and interpreting data and observations. | As part of developing the learning goal or after a learning goal has been developed (as a use-and-apply activity) | To teach students how to organize, present, and analyze data in ways that will reveal important patterns and relationships that can be used in developing explanations |
| | Engage students in constructing explanations and arguments. | As part of developing the learning goal or after a learning goal has been developed (as a use-and-apply activity) | To engage students in using evidence and science ideas to explain observations and data and to develop arguments that assess the strengths and weaknesses of competing explanations |
| | Engage students in using and applying new science ideas in a variety of ways and contexts. | After the learning goal has been developed<br>Before the final unit assessment | To engage students in using newly learned science ideas to explain new situations, new phenomena, and new real-world connections<br>To demonstrate the wide usefulness and value of the new ideas |
| | Engage students in making connections by synthesizing and summarizing key science ideas. | After the learning goal has been developed | To engage students in making connections among ideas, evidence, and experiences they have encountered in the lesson(s) |
| | Engage students in communicating in scientific ways. | Anytime | To engage students productively in science practices and discourse |

## Strategies to Create a Coherent Science Content Storyline

## Introduction to the Science Content Storyline Lens

You've probably encountered science textbooks packed with a wealth of science content. Science textbooks are sometimes so loaded with information that it's difficult to unearth and understand the big ideas that might tie all the facts together. It may seem to you that the solution to this problem is to throw out the textbooks and teach science only through hands-on activities. However, research shows that *hands-on doing* does not automatically lead to *minds-on learning.* Teachers may present accurate science content and engaging hands-on activities, but these content ideas and activities often aren't carefully woven together to tell a coherent story. Students miss the point of the activities they're carrying out and instead pick up random pieces of scientific terminology without fitting the ideas together to develop rich conceptual understandings.

To help students develop more meaningful understandings, you can use the Science Content Storyline Lens to focus attention on how the science ideas in a lesson (or unit) are sequenced and linked to one another to build a coherent "story" that makes sense to students.

### What Is a Science Content Storyline?

A science content storyline consists of carefully chosen and sequenced science ideas that build on one another to illustrate a bigger picture (a big idea, a core science idea, or a crosscutting concept). This coherent set of science ideas creates a story within a lesson, as well as across lessons and units. The ideas flow from one to the next so that students can make the connections, just as they can follow and make sense of a good story. The central ideas of the story are emphasized, connected, and linked. Details are used to support the development of the central storyline but are kept to a minimum so they don't clutter and detract from the storyline.

There are two key points to keep in mind regarding coherent science content storylines. First, the storyline is about the *science ideas* in the lesson and how they are organized to tell a story about one big idea or crosscutting scientific concept. Second, the *activities* students carry out in the lesson and unit must engage them in making sense of this science content storyline, with the science ideas and terms explicitly linked to the activities. Thus, each activity helps develop a key part of the science content storyline.

### Why Is the Science Content Storyline Lens Important?

Looking at lessons through the Science Content Storyline Lens can help you identify places where students are likely to get confused because of gaps in the storyline, too much distracting information, or activities that aren't clearly linked to the science ideas. It also highlights exactly what knowledge students have access to during the lesson that will help them make sense of the main ideas.

Research results from the 1999 Third International Mathematics and Science Study (TIMSS Video Study) of 8th-grade science teaching in five countries (Roth et al., 2006) illustrate the importance of a clear science content storyline in a lesson. The video study found that US science lessons engaged students in carrying out a variety of activities. In contrast with higher-achieving countries, however, the science activities in US lessons were often used without clear links to the science ideas they might illustrate or support. In fact, more than 25% of the randomly selected US science lessons were almost entirely activity focused, with little or no explicit teaching of science-content ideas. Students simply followed directions and carried out activities without being required to think about scientific explanations or engage in scientific reasoning. In higher-achieving countries, however, lessons were structured to build a clear, coherent science content storyline. All parts of the lesson, including hands-on activities, were closely linked and used to build a story about one science concept.

*A Framework for K–12 Science Education* (NRC, 2012) also emphasizes the importance of helping students develop a “coherent … understanding of science” (p. 25). But many students leave their science classes holding “disconnected and even contradictory bits of knowledge as isolated facts” (p. 25), which they quickly forget when the test or the course is over. Students typically experience science as a sequence of discrete chapters or units and miss the important connections among the ideas in these chapters/units that will help them deeply understand key concepts. Students often view each day’s lesson as linked to the previous only by topic, not by an overarching question or crosscutting concept. They don’t expect that ideas and activities experienced in a unit or chapter at the beginning of the school year will have much at all to do with a unit or chapter studied in the spring.

Research shows that we can do better as science teachers by helping students develop deeper understandings of core principles that they can use to “make sense of new information or tackle novel problems,” as experts do (NRC, 2012, p. 25). According to the National Research Council (2012), “Research on learning shows that supporting development of this kind of understanding is challenging but aided by explicit instructional support that stresses connections across different activities and learning experiences.… To develop a thorough understanding of scientific explanations of the world, students need sustained opportunities to work with and develop the underlying ideas and to appreciate those ideas’ interconnections over a period of years rather than weeks or months” (pp. 25–26).

**What Is Challenging about Developing a Coherent Science Content Storyline?**

Developing a coherent science content storyline is especially challenging when you engage students in using scientific-inquiry practices. Students can be actively engaged in predicting, observing, and manipulating materials without making any connections to science ideas and explanations—that is, students can be busily *doing* the activity without thinking about and learning from it. But this isn’t how science works. Scientists don’t predict and observe without thinking about and making connections to what they already know. Instead, they use scientific practices and the science ideas they already grasp to develop better understandings of important ideas and phenomena. This idea-focused work is what students should do in their science-inquiry activities as well. Otherwise, they’ll develop the misconception that science is all about measuring, observing, and predicting and miss the point that the essence of science is about using those practices to build better understandings and explanations of phenomena in the world around us.

Developing a coherent science content storyline is also challenging when you’re simultaneously using a Student Thinking Lens to make student thinking visible in the lesson. How will you weave the student ideas that arise during the lesson into your planned science content storyline? Your goal should be to use students’ ideas to shape how the science content storyline unfolds (within and across lessons). Before teaching, therefore, you need to anticipate student ideas that might arise and determine how those ideas will affect the science content storyline. While teaching, you must make meaningful adjustments to the planned science content storyline as a result of student ideas that emerge.

**What Strategies Support the Planning and Teaching of a Coherent Science Content Storyline?**

In this section, we’ll examine the following planning and teaching strategies that help create a coherent content storyline within and across science lessons:

- Identify one main learning goal.

- Set the purpose with a focus question or goal statement.
- Select activities that are matched to the learning goal.
- Select content representations and models matched to the learning goal and engage students in their use.
- Sequence key science ideas appropriately.
- Make explicit links between science ideas and activities.
- Link science ideas to other science ideas.
- Highlight key science ideas and focus question throughout.
- Summarize key science ideas.

## Strategies to Create a Coherent Science Content Storyline

### STeLLA Strategy A:
### Identify One Main Learning Goal

Research suggests that science lessons often contain too many science ideas, and that these ideas are presented as a list of facts to memorize rather than a big idea or concept that is useful in explaining and predicting the outcome of events in the world around us. Teachers may present accurate science ideas and engaging hands-on activities, but they may be either too numerous or not carefully woven together to create a coherent story. As mentioned earlier, students often miss the point of the activities they're carrying out and instead pick up bits and pieces of scientific terminology without fitting the ideas together to develop rich conceptual understandings.

The Science Content Storyline Lens focuses attention on how the science ideas in a lesson are sequenced and linked to one another and to lesson activities to help students construct a coherent "story" that makes sense to them. The first step in creating a coherent science content storyline in a lesson is to identify the main learning goal. What *big idea* or crosscutting concept do you want students to learn in this lesson?

A main learning goal IS …

- a big idea (a core science idea or a crosscutting concept) that students are expected to learn and take away from this lesson (or series of lessons).
- a big idea (a core science idea or a crosscutting concept) that shows the relationship among science ideas and can be used to explain multiple phenomena.
- the focus of the lesson (or sometimes a series of lessons) that organizes supporting science ideas, activities, and essential vocabulary terms.
- stated in a complete sentence(s).
- stated by the teacher, a student, a text, or a multimedia program.

The main learning goal should be a core science idea or crosscutting concept that shows the relationship among science ideas and can be used to explain a variety of phenomena. Supporting details or facts aren't appropriate as main learning goals (e.g., "A water molecule has two hydrogen atoms and one oxygen atom," or "Plants are able to absorb sunlight because of chlorophyll in their cells," or "The equation for photosynthesis is …"). A main learning goal is an important science concept that warrants at least 40 minutes of lesson time (and possibly more time over a series of lessons). A helpful way to define a main learning goal is to complete the statement, "I want my students to understand and be able to reason using the core science idea that … [*state the learning goal in a complete sentence*]."

The main learning goal should be stated in a complete sentence so it's clear and specific. When you state learning goals as topics or phrases, you aren't challenging yourself to identify exactly what is to be learned and assessed. For example, the phrase "matter cycling in food webs" sounds good on the surface, but what exactly do you want students to understand about matter cycling? Will you focus on how matter enters the food web as carbon dioxide and water molecules that producers transform into energy-providing food matter? Do you want students to understand how each organism in the food web uses the matter in their food to grow? Do you also want students to understand that each organism uses its food to release energy it needs to live (cellular respiration)?

What do you want students to understand about decomposers? Will it be enough for them to know that decomposers break matter into small pieces? Or do you want them to know that decomposers break down matter into carbon dioxide, water, and minerals? Is it enough to say that plants can use these tiny pieces again? Or do you want students to understand that these tiny pieces aren't food matter for plants, but plants can use them?

A main learning goal IS NOT …

- a topic or phrase (such as the water cycle, condensation, food webs, photosynthesis).
- an activity (such as making a cloud in a bottle to study condensation or playing with a computer simulation).
- a question (such as "How does a bird get the energy it needs to fly?").
- a performance task or objective (such as "Design and conduct an investigation showing how decomposers break down matter" or "Describe how matter is recycled in a food web").
- a supporting detail, definition, or fact (such as "Rabbits and giraffes are herbivores.").
- a misconception—a student idea that isn't scientifically accurate.

When planning and teaching science lessons, it's important to keep in mind the complete core science idea you want your students to learn. Therefore, a main learning goal is *not* a topic or phrase (e.g., "water molecules" or "producers and consumers in food webs"). A topic or phrase lets students know what the lesson is about, generally; however, it doesn't clearly state the central idea that students should come to understand from the lesson. In such an "all about" type of lesson, students might learn a bunch of stuff but feel unsure how that stuff is related and organized as a larger science idea. Such a lesson won't have a coherent science content storyline.

An activity is also not a learning goal. Although you want students to "do science" (e.g., observe and explain water condensing on a glass, or observe and explain mold decomposition of a piece of bread in a baggie), it's important to keep in mind the essential knowledge you want them to take away from those activities. For example, "evaluating a food-web diagram in terms of what happens to matter" isn't considered a main learning goal because it doesn't clearly state a complete science concept students should learn. In contrast, "producers make their own food using energy from the Sun, and consumers, including decomposers, get their energy by eating other organisms" *does* represent a complete science idea that students should learn.

A question isn't a main learning goal either. Although questions may set up the lesson, they aren't explicit statements about the science concept students should learn.

Other science ideas and vocabulary words support the main learning goal, but they should be organized in such a way that they focus on and develop the main learning goal. Therefore, focusing on one main learning goal while you plan and teach a science lesson will help you build a coherent science content storyline.

**Examples and Nonexamples of Main Learning Goals**

| | Main Learning Goal | NOT a Main Learning Goal |
|---|---|---|
| **Matter, Molecules, and the Water Cycle** | • Water changes state as a result of heat energy being added or lost.<br>• Evaporation occurs when water molecules in the liquid state gain energy and move fast enough to break away from one another.<br>• Water changes state but never disappears in Earth's water cycle. | • States of matter *(Topic)*<br>• The water cycle *(Topic)*<br>• Reasoning about observations of water appearing on a cold soda can *(Activity)*<br>• Where does the water go when it evaporates? *(Question)*<br>• Evaporation and changes of state *(Not a complete sentence)*<br>• Rain and snow are forms of precipitation. *(Factual statement, not a big idea)* |
| **Food Webs** | • Producers make their own food using energy from the Sun.<br>• Plants are the primary source of energy entering any food web.<br>• Decomposers recycle matter by breaking down dead organisms into small pieces. | • Consumers and producers *(Topic)*<br>• Bread molding *(Activity)*<br>• How do primary consumers get the matter and energy they need to live? *(Question)*<br>• Matter cycling in food webs *(Not a complete sentence)*<br>• Fungi and bacteria are decomposers. *(Factual statement, not a big idea)* |

## Strategies to Create a Coherent Science Content Storyline

### Analysis Guide A:
### Identifying One Main Learning Goal

State the main learning goal being analyzed: ____________________________________________

______________________________________________________________________

______________________________________________________________________

| Criteria for Main Learning Goal | Yes | No |
|---|---|---|
| 1. Is the main learning goal stated in a full sentence that represents a science idea (not a topic, phrase, activity, or question) that students could take away with them at the end of a lesson? | | |
| 2. Do the students already know the science content reflected in the learning goal? If yes, you need to make the learning goal more challenging. | | |
| 3. Is the learning goal an important science idea?<br>a. It is worthy of 40 minutes or more being spent on it.<br>b. It has important connections to other science ideas and can be used to explain a variety of phenomena.<br>c. It is a big idea, a key concept, and not just a supporting fact, example, or detail. | | |
| 4. Do students have misconceptions or confusion about this science idea? | | |
| 5. Does this learning goal challenge students' thinking and/or misconceptions? If there is evidence that students already understand the learning goal, it isn't meaningful. | | |
| 6. Is the learning goal grade-level appropriate and matched to state and/or national standards? | | |
| 7. Is the learning goal scientifically accurate? | | |

Suggest how to improve the main learning goal: ________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

## Strategies to Create a Coherent Science Content Storyline

## STeLLA Strategy B:
## Set the Purpose with a Focus Question or Goal Statement

The science content storyline in a lesson begins with a focus question or goal statement that directs students' attention to the main learning goal for the lesson. An appropriate focus question or goal statement should be closely matched to the lesson's main learning goal (not just the activities), should be worded in language students can understand at the beginning of the lesson, and should avoid scientific terminology they might learn later in the lesson. The focus question may serve as a way to elicit a variety of student ideas at the beginning of the lesson, as an organizer throughout the lesson, and as a way to assess student understanding at the end of the lesson.

The ideal uses of a focus question or goal statement are to

- elicit students' initial ideas at the beginning of the lesson,
- engage student interest in the science content,
- serve as an organizer throughout the lesson (e.g., "Does this activity contribute any new information about our focus question?"), and
- bring closure to the science content storyline at the end of the lesson (e.g., "Can you summarize what you've learned about our focus question?").

### How Is the Focus Question/Goal Statement Related to the Main Learning Goal (Strategy A)?

Focus questions and goal statements are used to help students understand the purpose of the lesson without stating the main learning goal itself. In some subject areas and schools, teachers are encouraged to state the complete main learning goal (or standard) at the beginning of the lesson. In science, however, we want students to construct understandings of the main ideas through the use of scientific practices and reasoning. We want them to investigate scientific questions. The focus question supports this process and also provides a lesson framework that surrounds the development of the main learning goal without giving away the "punch line" at the beginning of the lesson. The main learning goal should guide the selection of the focus question or goal statement, resulting in a close alignment between them.

**Examples of Focus Questions and Goal Statements**

| Matter, Molecules, and the Water Cycle | | | | |
|---|---|---|---|---|
| | **Main learning goal:** Changes in the energy (motion) of molecules help explain how water changes state during evaporation and condensation. | | | |
| | | **1. NOT Closely Linked to the Main Learning Goal** | **2. NOT Understandable and Engaging to Students (Uses Scientific Terminology)** | **3. Is Linked to the Learning Goal and Is Understandable and Engaging to Students** |
| | **Focus Question** | What are the three states of matter? | How can you make ice change states? | How can you make water seem to disappear or reappear? |
| | **Goal Statement** | We're going to learn about the three states of matter in the water cycle. | We're going to learn how water changes states when heat energy is added. | We're going to learn what happens when water changes from a liquid to a gas. |

| Food Webs | | | | |
|---|---|---|---|---|
| | **Main learning goal:** Plants are the primary source of energy entering any food web. Energy is transferred between organisms through the consumption of food. | | | |
| | | **1. NOT Closely Linked to the Main Learning Goal** | **2. NOT Understandable and Engaging to Students (Uses Scientific Terminology)** | **3. Is Linked to the Learning Goal and Is Understandable and Engaging to Students** |
| | **Focus Question** | What is energy? | What is a food web? | Where do we get the energy we need to live and move? |
| | **Goal Statement** | Today we're going to learn about energy. | In this lesson, we're going to learn about energy and how it's transferred in food webs. | Today we're going to learn about how different organisms get the energy they need to live. |

## Strategies to Create a Coherent Science Content Storyline

## Analysis Guides B and I:
## Setting the Purpose and Summarizing Key Science Ideas

| Criteria for Strategy B: Setting the Purpose | Yes | No |
|---|---|---|
| 1. Does the focus question or goal statement help students anticipate one main learning goal for the lesson? If yes, write the implied main learning goal here: | | |
| 2. Does the focus question or goal statement use everyday language that students will understand at the beginning of the lesson? If no, what words need to be changed? | | |
| 3. Is the focus question or goal statement presented in a scientifically accurate way? If no, what is inaccurate? | | |
| 4. Would the goal statement be improved if it were turned into a focus question? If yes, provide a suggested focus question here: | | |

| Criteria for Strategy I: Summarizing Key Science Ideas | Yes | No |
|---|---|---|
| 1. Is there some kind of summary statement or activity in the lesson? | | |
| 2. Does the summary focus on conceptual understanding and not just a list of facts or activity procedures? | | |
| 3. Do the science ideas in the summary match the main learning goal and the focus question or goal statement? | | |
| 4. Is the summary statement/activity scientifically accurate? | | |
| 5. Are students engaged in making sense of the summary statement? | | |
| 6. Could the summary be improved? Write suggested modifications on the back of this page. | | |

## Strategies to Create a Coherent Science Content Storyline

### STeLLA Strategy C:
### Select Activities That Are Matched to the Learning Goal

Student activities in science classrooms come in many forms—observing phenomena, constructing models, drawing diagrams, conducting experiments, interpreting graphs, discussing ideas in a small group, completing a worksheet, reading from a textbook, answering questions, carrying out a role-play, and more. Too often, however, science activities are selected for the wrong reasons, such as because they're easy and cheap to do or fun for students. While it's important to consider activities that are manageable, affordable, and engaging to students, these aren't adequate reasons for choosing an activity.

An activity can help develop the science content storyline only if it is closely matched to the main learning goal. So the most important question to ask when selecting activities is this: "Does the activity provide opportunities for students to understand the main learning goal of the lesson?" If an activity doesn't closely match the main learning goal, it shouldn't be used, no matter how cool or fun it is.

Activities that are matched to the main learning goal can help develop the science content storyline by doing one or more of the following:

- Challenging common student misconceptions related to the main learning goal
- Providing observable evidence to support or help develop the main learning goal through student interpretation and reasoning
- Presenting new information about the main learning goal in ways that students can understand
- Guiding students in developing an understanding of the main learning goal
- Providing opportunities for students to practice using and applying new ideas about the main learning goal in a variety of real-world situations
- Providing opportunities for students to synthesize and make connections among ideas that support the main learning goal

Activities that are matched to the learning goal DO NOT …

- include ideas, details, or steps that distract from the main learning goal, or
- reinforce common student misconceptions.

## Examples of Activities Closely Matched to the Learning Goal

### *About Matter, Molecules, and the Water Cycle*

| **Learning goal:** When water-vapor molecules lose heat (cool), they slow down and move closer together to form liquid water. This process is called *condensation*. | |
|---|---|
| **Activities NOT CLOSELY MATCHED to the Learning Goal** | **Activities CLOSELY MATCHED to the Learning Goal** |
| Students read about evaporation, condensation, and precipitation and then use these words to label a diagram of the water cycle. | In small groups, students observe water droplets form on the outside of a glass of ice water. Then they're challenged to use what they know about molecules to explain this phenomenon. Afterward, students share their ideas in a class discussion and read about what happens to water molecules as they change from a gaseous state to a liquid state during condensation. They use these ideas to explain their observations of the glass of ice water. |

### *About Food Webs*

| **Learning goal:** Although matter changes form (state) and moves from organism to organism in food webs, no matter is ever lost or destroyed. The total amount of matter in the system remains the same. | |
|---|---|
| **Activities NOT CLOSELY MATCHED to Learning Goal** | **Activities CLOSELY MATCHED to Learning Goal** |
| The teacher selects 10 students to stand up. Each student is identified as an organism in a food web (e.g., grass, rabbit, caterpillar, snake, bird, hawk, bacteria) and is given several strands of string. The teacher asks each "organism," "Where do you get your food matter and energy?" The organisms then use the string to connect themselves to their sources of food matter and energy. The result is a dramatic visualization of the complexities of a food web and how organisms get their food matter and energy.<br>Fun, but off target! | In a role-play, students use linking cubes to represent carbon dioxide, water, and sugar molecules. They model how each organism in a food chain changes matter and uses it. For example, producers break apart water and carbon-dioxide molecules and put them together in a new way to make food molecules. Producers use this food matter to grow bigger and release the energy they need to live. Some of this matter drops to the ground as wastes (dead leaves, branches), and finally, an herbivore eats part of the producer. The role-play continues with the herbivore and then a carnivore. As students rearrange and move the linking-cubes molecules, they stop periodically to count the cubes. No matter how much movement and rearranging has occurred, the total number of cubes (matter) is always the same. |

## Strategies to Create a Coherent Science Content Storyline

### Analysis Guide C:
### Selecting Activities Matched to the Learning Goal

List the main learning goal: ______________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

**Part 1:** Identify and analyze the science ideas in the activity. Using the table below, first list in the left column each science idea (main and supporting) that is addressed in the activity. Then indicate in the right column how closely each idea matches the main learning goal.

| **All Science Ideas in the Activity**<br><br>**(Name of Activity)** | The science idea is (*closely, partially, weakly, not*) matched to the main learning goal. |
|---|---|
| 1. | |
| 2. | |
| 3. | |
| 4. | |
| 5. | |
| 6. | |
| 7. | |
| 8. | |
| 9. | |
| 10. | |

**Part 2:** If there are weak or partial matches, suggest ways the activity could be modified to more closely match the main learning goal.

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

## Strategies to Create a Coherent Science Content Storyline

## STeLLA Strategy D:
## Select Content Representations and Models Matched to the Learning Goal and Engage Students in Their Use

Although students need opportunities to conduct investigations and gather evidence to build explanations, they cannot be expected to construct understandings held by the scientific community from firsthand evidence alone. Their understandings of their investigations will grow as they also learn about the core science ideas and crosscutting concepts that scientists have constructed over the history of science. How will you give students access to these science ideas?

There are a variety of ways of doing this. Two of the most common are (1) telling students about it (e.g., lecturing) and (2) having students read about it in a textbook or other source. These traditional approaches can play a role in instruction but aren't adequate to help a diverse group of students understand science concepts that are often complex, abstract, and even counterintuitive. Using content representations, such as analogies, metaphors, diagrams, charts, graphs, concept maps, models, videos, simulations, and role-plays, can help make science ideas more concrete and real for students. Content representations can be especially useful in helping students see how the science content storyline fits together. For example, students can construct diagrams or concept maps to show their understandings of how the ideas they've been studying are connected.

Representations of real-life phenomena are also useful when the phenomena are difficult or impossible for students to observe firsthand in a classroom setting (e.g., energy transformations, molecular motion, photosynthesis, bacteria). Representations can help students imagine things they can't see in a classroom setting—things that are too small, too large, too far away, or too abstract; things that no longer exist on Earth; or things that occur too quickly or slowly for students to perceive firsthand.

One type of representation translates scientists' mental, or conceptual, models into artifacts that can be shared with others, including diagrams, animations, or 3-D constructions. These models are especially important in scientific reasoning, and students should be engaged in learning how to construct and represent their own models, as well as how to use others' models. Like scientists, students can *build* mental models to help with reasoning about phenomena and then create representations of these models. For example, students might consider what happens when a puddle evaporates and then draw diagrams that represent their thinking. Students can also deepen their understandings by *using* scientists' models to make sense of phenomena they observe. For example, students might watch an animation depicting scientists' understandings of how water molecules behave in solid, liquid, and gaseous states, and then use that conceptual model to reason about a variety of phenomena involving water molecules, such as steamed-up mirrors, clouds, and boiling water.

**Examples of Representations on Matter, Molecules, and the Water Cycle**

- A graph showing the water level in a cup of water that sits out for 10 days
- Role-play of water molecules and how they move in different states of matter
- A diagram of the water cycle

**Examples of Representations on Food Webs**

- A Venn diagram to compare/contrast how energy and matter move in food webs

- Use of a mixing bowl, a hand mixer, water, a baggie full of air, a flashlight (Sun), and sugar to demonstrate the process of photosynthesis

**Sample Analyses of Content Representations**

**Example 1a. The Water Cycle: Using the Criteria in Selecting Content Representations**

*Main learning goal:* Earth's water is conserved in the cycling processes of evaporation, condensation, and precipitation as heat energy is gained and lost.

*Content representation:* Set up a closed (cap on) 2-liter-bottle system that has a small amount of water in the bottom of the bottle. As the water in the bottle evaporates, some of it condenses on the wall of the bottle and "rains" (drips) back down the side of the bottle. The bottle system serves as a miniature model of Earth's water cycle.

**Analyzing the Water-Cycle Bottle Representation**

*Is the 2-liter bottle system a scientifically accurate model of the water cycle*? Because this model includes actual observations of firsthand phenomena in Earth's water cycle (evaporation, condensation, and precipitation), it shows these processes accurately. In fact, these observations aren't representations at all; they're the real thing! As a model of Earth's water cycle, however, the bottle doesn't make visible the importance of a heat source (the Sun) and the heating and cooling processes that drive the water cycle. This is the biggest weakness of the model from a scientific point of view. In addition, the condensation on the inside of the bottle is not the same as what happens in cloud formation. In clouds, water molecules condense around small particles in the air and hang suspended as tiny droplets (not clinging to the side of a bottle). Similarly, the precipitation in the bottle is really condensed water drops sliding down the side of the bottle rather than water drops falling from clouds in the air at the top of the bottle.

*Is the model closely matched to the main learning goal of the lesson?* The 2-liter-bottle model is well matched to the part of the learning goal about evaporation, condensation, and precipitation because students can actually observe these phenomena firsthand. The role of heating and cooling isn't addressed in the model. This could easily be fixed by shining a light on the bottle. The part of the main learning goal about conservation of water is not obvious from observing the model and would have to be emphasized in discussions about the model.

*Is this model likely to make sense to young students?* Students are able to observe the phenomena of evaporation and condensation. Precipitation is harder to observe. It's also difficult for students to understand where heating and cooling is happening—even with a lamp, they might assume there is more heat at the top of the bottle, where condensation is occurring, than at the bottom, where evaporation is occurring. But the biggest problem students could have is seeing the bottle system as a representation of Earth's water cycle. It may not be obvious to them that the bottle represents Earth. This makes it difficult for them to connect what they see happening in the bottle with the same processes happening in the world around them.

*Might the model introduce or reinforce misconceptions about the water cycle?* The model might reinforce students' assumptions that the water cycle always happens at room temperature. For example, the model includes no consideration of how the water cycle might change in freezing temperatures.

*Does the model distract students from the main learning goal with too many details or new terms?* No, the model focuses on the central processes in the water cycle and appropriately leaves out potentially distracting ideas, such as groundwater infiltration and plant transpiration.

*Suggestions for improving the model:* (1) Add a lamp to the system to represent the Sun and allow for more discussion about heating and cooling. Have students identify and label where heating and cooling are happening in the bottle. (2) Discuss how water is conserved within the system: “Is any water escaping or disappearing?” To emphasize the conservation of water, the bottle could be weighed before and after the cycle has started.

**Example 1b. The Water Cycle: Engaging students in *Using* Content Representations**

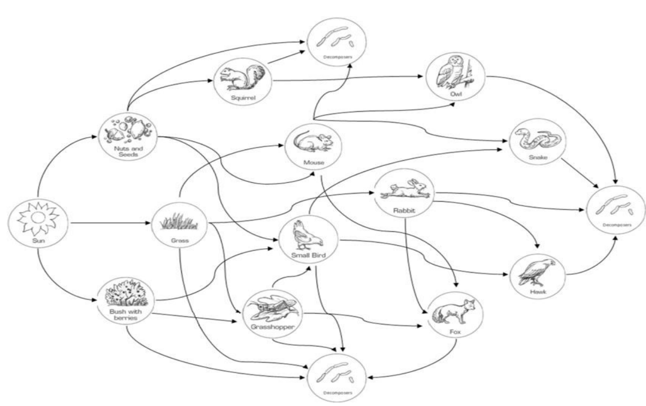
Instead of simply showing students the water-cycle bottle representation, engage them in using or modifying the representation. For example, you could do the following:

- Have students observe the 2-liter bottle. Then give them a diagram of the water cycle that includes representations of the Sun, clouds, rain, snow on mountaintops, lakes, and rivers. Have them find similarities between the two representations. Then look at differences: How is the bottle representation different from the diagram? Is the diagram of Earth’s water cycle a better model? Why or why not?
- Have students draw a diagram of the 2-liter bottle and label where evaporation, condensation, and precipitation occur. Ask them to also draw arrows to show how water moves in a cycle within the bottle system.
- After students observe the 2-liter bottle and draw arrows to show how water moves in a cycle, show and discuss a web-based simulation of a water cycle. (Before viewing with students, review the simulation yourself and make sure the web content is scientifically accurate.)
- After students view and discuss the simulation, have them return to their drawings of the 2-liter-bottle model and compare and contrast the model with the web-based simulation. You might also ask students to consider how the 2-liter-bottle model and the simulation on the website relate to the actual water cycle on Earth.

**Example 2a. Food Webs: Using the Criteria in *Selecting* Content Representations**

*Main learning goal:* Decomposers recycle matter by breaking down dead organisms into minerals, carbon dioxide, and water that plants can use again.

*Content representation to be analyzed:* meadow food-web diagram



**Analyzing the Meadow Food-Web Diagram**

*Is this model scientifically accurate?* Because this diagram starts with the Sun, it is *not* an accurate representation of how matter cycles in a food web. Instead, it accurately depicts how energy flows in a food web from the Sun to producers and then from producers to consumers to decomposers.

*Is the model closely matched to the main learning goal of the lesson?* The representation clearly shows that decomposers eventually consume all organisms, but it doesn't show decomposers leaving behind matter that plants (producers) can use again. Therefore, this diagram is *not* closely matched to the main learning goal.

*Is this model likely to make sense to young students?* The diagram is likely to make sense to students if they're tracking energy flow in the food web. However, they aren't likely to be able to use this diagram to conclude that matter is recycled.

*Might the model introduce or reinforce misconceptions?* If students are asked to use the diagram to trace the cycling of matter, they might assume that the Sun is matter or that it provides matter to living things in a food web.

*Does the model distract students from the main idea with too many details or new terms?* The diagram is simple and isn't overloaded with details and scientific terms. However, the presence of the Sun is likely to distract students from focusing on the matter-cycling idea, which is the focus of the main learning goal.

**Example 2b. Food Webs: Engaging Students in *Using* the Meadow Food-Web Diagram**

This diagram could be useful in a synthesis activity related to a different learning goal. For example: *Within a food web, matter is continually recycled and reused, but energy is used up and lost as heat that cannot be reused by living things*. The synthesis task could challenge students to modify the meadow food-web diagram to contrast how matter and energy are used in a food web. First, students could use a red pencil to trace the flow of energy and add words/labels that show how energy moves in a food web. For each organism, they might add words like "uses some energy" and have an arrow showing the organism "giving off heat." Next, they could be challenged to use a blue pencil to add words and arrows showing how matter moves in a food web. They might add carbon dioxide and water going into the producers to make food, and then show the decomposers giving off carbon dioxide, water, and minerals that can cycle back to the producers. A final step in the task is to write a summary that compares how matter and energy move in food webs.

## Strategies to Create a Coherent Science Content Storyline

## Analysis Guide D:
## Selecting and Using Content Representations

Main learning goal: ______________________________________________

______________________________________________

Description of content representation: ______________________________________________

______________________________________________

**Part 1: Selecting the Content Representation**

| **Is the Content Representation …** | **Yes** | **No** |
|---|---|---|
| 1. Scientifically accurate? | | |
| 2. Closely matched to the main learning goal? | | |
| 3. Presenting science ideas in ways that are comprehensible to students? | | |
| 4. Reinforcing or introducing student misconceptions? | | |
| 5. Addressing common student misconceptions? | | |
| 6. Distracting students from the main learning goal with too many details or new terms? | | |

**Part 2: Engaging Students in Using the Content Representation**

| **Is the Content Representation Used in a Way That Involves Students In …** | **Yes** | **No** |
|---|---|---|
| 1. Modifying or creating the content representation? | | |
| 2. Analyzing the meaning of the content representation? | | |
| 3. Critiquing the content representation? | | |

**Part 3: Suggestions for Improvement**

______________________________________________

______________________________________________

______________________________________________

## Strategies to Create a Coherent Science Content Storyline

### STeLLA Strategy E:
### Sequence Key Science Ideas and Activities Appropriately

Sequencing of key science ideas and activities is critical to the development of coherent science content storylines both within and across lessons. Coherent sequencing is also important across units and school years.

**Sequencing across Lessons, Units, and Years**

Because it takes time for students to develop meaningful understandings of core science ideas and crosscutting concepts, lessons—and even units—need to carefully build on one another. All the lessons in a given unit should address the same overarching question—sometimes called a *driving question* or a *central question*. As the lessons proceed, students should be able to track their evolving understandings related to this overarching question. For example, a 5th-grade unit about the water cycle might be organized around the central questions, "How does water change in the world around us? Will Earth ever run out of water?" To answer these questions, students develop understandings of core science ideas about changes in matter during evaporation and condensation and the relationship of these processes to the gain and loss of heat. A unit about food webs in a 5th- or 6th-grade classroom might address the driving question, "What would happen to life on Earth if there were no plants?" Addressing this question would involve investigations of the role of plants as producers, the flow of energy from the Sun to producers to consumers, and the cycling of matter in food webs. At the end of each day's lesson, students should be able to reflect on new ideas related to the central question as well as remaining unanswered questions to be investigated.

In a similar way, there should be strong connections across units during the school year and across school years. At the end of the school year, for example, students should be able to describe how all the units they studied fit together. They should also be able to identify and use important crosscutting concepts.

Research shows the value of such a connected curriculum. Allison is a student who struggled academically. During her 5th-grade year, she experienced a science curriculum that had a strong science content storyline across units. At the end of the school year, as she helped her teacher take down the class science bulletin boards, Allison started telling the story of her 5th-grade science learning in an impromptu conversation with her teacher:

> You know, Ms. Ashton, all that stuff we studied in science this year, it all kind of fit together in the end, didn't it? I mean, we learned how plants make food, and then we learned how we use the food plants make in our cells. And then we learned about how food and energy and stuff go in ecosystems. And how the first living things were like one-celled plants, and it's like it all goes back to the plants.

Josh, another student in this class, was watering the classroom plants one day when he remarked, "You know, Ms. Ashton, I used to think that plants just sit there, but they're actually quite busy little things, aren't they?"

Other students in this class were interviewed a year later, at the end of 6th grade, and they were still able to make meaningful connections among ideas about plants making energy-containing food out of non-energy-supplying raw materials (air and water), the chemical reactions taking place in the cells of all living things that release the energy stored in food, the cycling of matter, and the flow of energy in ecosystems. This kind of connected understanding took time to develop and an explicit focus on connecting core ideas.

The students weren't taught many of the details that are typically taught about photosynthesis, cellular respiration, and energy transfer. But they developed a strong understanding of some connected core ideas that stuck with them and proved useful to them as ways of thinking about the world. Such understandings grew out of a clear, explicit science content storyline across the school year.

Some important resources can help you plan meaningful sequences of science ideas and concepts across units and school years. The American Association for the Advancement of Science (AAAS) has produced two atlases with Strand Maps that show how core science ideas related to a variety of science ideas (e.g., atoms and molecules, cell functions, gravity, energy in living systems) might be sequenced across K–12 grade levels (AAAS, 2001, 2007). Additional information can be found in the National Research Council report *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012) and in the *Next Generation Science Standards* (NGSS Lead States, 2013).

Before turning to sequencing within lessons, we leave you with this quote from the NRC report (2012), which reminds us that meaningful understandings take time to develop, and that coherence needs to be developed at multiple levels: within lessons, across lessons, across units, and across school years.

> *Research on learning shows that supporting development of this kind of [science] understanding is challenging, but it is aided by explicit instructional support that stresses connections across different activities and learning experiences.… To develop a thorough understanding of scientific explanations of the world, students need sustained opportunities to work with and develop the underlying ideas and to appreciate those ideas' interconnections over a period of years rather than weeks or months.* (NRC, 2012, pp. 25–26)

**Sequencing within Lessons**

The order in which various content ideas, terms, and activities are introduced within a lesson should be carefully planned so that the sequence of ideas is clear and the sequence of activities supports the development of the ideas. It's important to first get clear on the main learning goal and supporting ideas to be developed. What is a sequence of ideas that will make sense as a story to your students? Keep in mind that a typical problem in sequencing lessons is the inclusion of too many ideas, which makes it difficult for students to find a clear storyline. Activities should be selected after the main learning goal and key supporting ideas have been selected and the science ideas have been sequenced into a strong storyline. Ask yourself these important questions: Will the activity enhance the development of the ideas and storyline? Which activities will help create a clear and meaningful flow of ideas for students?

There are a variety of ways to sequence science ideas and activities in a lesson. One approach is to begin with a discussion of the focus question, followed with an investigation to gather data about the question. The interpretation of data collected during the activity is then used to help students develop explanations and understandings of a new science idea. In this case, the new ideas and relevant terms are introduced somewhat late in the lesson, arising out of a need to describe what students observe or how they're making sense of the activity.

Another approach is to answer the focus question close to the beginning of the lesson by explaining ideas to students or having them read or watch a video about a new idea. This presentation of new ideas might be followed with a series of activities that allow students the opportunity to use and discuss the new ideas in a variety of real-world contexts. For example, a teacher might introduce some key ideas about how water molecules behave in the solid, liquid, and gaseous states and then have students use those ideas to explain real-world phenomena, such as "foggy" bathroom mirrors, morning dew on the grass, or wet towels drying on a clothesline.

Although the NRC *Framework* and the NGSS emphasize helping students construct understandings from their investigations of data, there is no one right way to sequence the storyline of a lesson. The most important questions to ask are as follows:

- Is the storyline closely matched to the main learning goal?
- Is the progression of science ideas clearly laid out (i.e., a clear beginning, middle, and end)?
- Are there any gaps or holes in the flow of science ideas?
- Is the storyline cluttered with too many ideas, distracting ideas, or "orphan" ideas (ideas that are mentioned but aren't central to the storyline)?
- Are ideas scientifically accurate?
- Are activities closely matched and linked to the science ideas in the storyline?
- Will the lesson activities engage students in thinking about the main learning goal and supporting science ideas (versus just doing the activity)?
- Are there markers, such as focus questions, linking statements, summary statements, or highlighted statements, that help tie the science content storyline together?
- Will the storyline be visible and make sense to students?

See the following examples of weak and strong lesson sequencing.

**The Water Cycle: Weak Example of Sequencing**

This lesson example is weak because there are too many science ideas and activities, without a clear focus on one main learning goal. This is what we refer to as an "all about" lesson—in this case, "all about the water cycle." Also, the ideas about evaporation, condensation, precipitation, cycles, and types of clouds aren't connected to one another in any logical sequence. The lesson starts with a focus on cycles, but the idea of cycles isn't addressed in the lesson activities.

| Weak Sequence of Water-Cycle Science Ideas | Weak Sequence of Water-Cycle Activities |
|---|---|
| Cycles are when things go around and around. There is no beginning and no end—things happen over and over again. | Today we're going to learn about the water cycle. What does the word *cycle* make you think of? |
| There are many different types of clouds. | *Activity 1:* Students compare photos of different kinds of clouds. |
| Evaporation is when liquid water goes into the air. | *Activity 2:* Observe a pot of boiling water. What happens to the level of liquid in the pot over time? Is the water disappearing? What is happening to the water? |
| Moisture forms on a cold soda can because water vapor in the air is cooled. When water vapor is cooled, it changes into liquid water. This is called *condensation*. | *Activity 3:* Students observe a cold soda can with water droplets formed on the outside.<br>Why is this soda can wet on the outside? |
| | *Lesson ending:* What did you learn today about the water cycle? |

**Food Webs: Weak Example of Sequencing**

This lesson example is weak because the main learning goal is unclear. Students are supposed to be learning about food chains, but it isn't clear what they're supposed to learn. The first activity focuses on identifying plants and animals in different habitats as well as their needs. This introduces ideas that aren't connected closely to the idea of food chains and therefore might be distracting to students. The second activity emphasizes that all living organisms need food but does nothing to support the development of the idea that these organisms are connected in food chains. In sum, the activities don't closely match the main learning goal, and the main learning goal is vague.

| Weak Sequence of Food-Webs Science Ideas | Weak Sequence of Food-Webs Activities |
|---|---|
| | Today we're going to learn about food chains in different habitats. |
| All plants and animals need food and water, but they have different ways of getting them.<br><br>Different plants and animals have different features that help them survive in particular habitats. | *Activity 1:* Students look at books with pictures of different habitats. Each small group makes a list of plants and animals that live in one kind of habitat. Then they answer these questions using resource books:<br>• How are the living things the same?<br>• How are they different?<br>• What characteristics of the plants and animals make them well suited to these habitats? |
| Habitats include a variety of living things. Each living thing in a habitat needs food. | *Activity 2:* Draw a picture showing a habitat you've visited. Be sure to label all the living things in your habitat. Circle the organisms that need food. |
| | *Lesson ending:* What did you learn today about living things and their habitats? |

**The Water Cycle: Strong Example of Sequencing**

In this lesson, there is a clear main learning goal that explains condensation in terms of energy loss (cooling). The lesson begins and ends with a focus question that is well matched to this learning goal. Lesson activities engage students in thinking about the focus question. In addition, the lesson begins and ends with clear links to other lessons, developing a storyline across lessons as well as within the lesson.

| Strong Sequence of Water-Cycle Science Ideas | Strong Sequence of Water-Cycle Activities |
|---|---|
| During evaporation, water changes from a liquid to a gas faster when heat energy is added. Water seems to disappear into the air, but the water is still there as a gas—we just can't see it. | The teacher revisits the idea of water changes: "What change of water did we investigate yesterday? (*Evaporation*). So we know there can be water vapor (a gas) in the air even though we can't see it." |
| | *Focus question:* "Can you make water vapor in the air 'reappear' as liquid water? If so, how? If not, why not?"<br><br>Students are given two glasses of water—one filled with room-temperature water, and one filled with ice water. They predict what will happen and why if the glasses sit for a while. |
| Water sometimes seems to reappear from the air, like when it forms drops on the side of a cold can or a cup filled with ice. | In groups, students record observations and suggest explanations for why water forms on the outside of the cold glass. |
| There's water vapor in the air, but we can't see it. We can make it reappear by bringing it close to something cold (e.g., something with less heat energy). As the water vapor loses heat energy ("cools," in everyday language), it comes together to form liquid-water drops. This process of changing water vapor from the air to liquid water is called *condensation*. | *Class discussion:* Why did water form on the outside of the glass of ice water but not on the outside of the glass of water at room temperature?<br><br>The teacher explains and highlights key science ideas using a diagram. |
| When water vapor in the air comes close to something cold, it loses heat energy (cools) and comes together to form liquid-water drops. This process is called *condensation*. | Students revisit the lesson focus question and synthesize their ideas by writing summary sentences and sharing them. |
| | The teacher summarizes key science ideas.<br><br>The teacher links science ideas to previous and next lessons: Yesterday we learned how water can seem to disappear into the air as water vapor we can't see. Today we saw how that water vapor in the air can reappear as liquid water if it loses heat energy (cools). Tomorrow we'll think about how these two processes—evaporation and condensation—work together in nature. |

**Food Webs: Strong Example of Sequencing**

In this lesson, there is a clear main learning goal. Students learn that in scientific terms, food is matter that contains energy living things can use to live and grow. By this definition, water and fertilizers ("plant food") are not food. The lesson begins and ends with a focus question that is well matched to this main learning goal: "What is food?" Each of the steps in this lesson focuses on this question and engages students in thinking and reasoning from evidence they gather.

| Strong Sequence of Food-Webs Science Ideas | Strong Sequence of Food-Webs Activities |
|---|---|
| | *Focus question:* "What is food?"<br><br>Elicit students' initial ideas: What is your definition of *food*? Write answers and reasoning to these questions:<br>• Is orange juice food?<br>• Is sugar food?<br>• Are vitamins food?<br>• Is "plant food" food for plants?<br>• Is water food? |
| Scientists define *food* as "matter (materials) that contains energy living things use to live and grow." | Students read the scientific definition of *food*.<br><br>By the scientific definition, is water food? Are vitamins food? Let's gather some evidence to help us answer these questions about food. |
| Water, vitamins, and "plant food" don't contain Calories, which is a measure of energy. | The teacher explains that the energy in food is measured in Calories.<br><br>The teacher distributes a variety of food containers with nutrition labels (including water, vitamins, and "plant food," which don't contain any Calories). Students use data from labels to figure out which of the materials is food for living things (provides Calories/energy). |
| Water and "plant food" are not food (by the scientific definition) because they don't provide energy for living things. | Using our evidence from the food labels and the scientific definition of food as energy-providing matter, answer these questions:<br>• Is orange juice food? (*Yes*)<br>• Is sugar food? (*Yes*)<br>• Are vitamins food? (*No*)<br>• Is "plant food" food for plants? (*No*)<br>• Is water food? (*No*) |

| Strong Sequence of Food-Webs Science Ideas | Strong Sequence of Food-Webs Activities |
|---|---|
| Food is matter that contains energy living things can use to live and grow.<br><br>Water and “plant food” are not really food for plants because they don’t provide plants with energy to live and grow. | *Lesson summary:* What did we learn today about our focus question, “What is food?”<br><br>Use the words *food* and *energy* to explain whether water and “plant food” are food by the scientific definition. |

## Strategies to Create a Coherent Science Content Storyline

### Analysis Guide E:
### Sequencing the Science Content Storyline within a Lesson

| Part 1: List All the Science Ideas in the Lesson in Sequence (Main Ideas, Supporting Ideas) | Part 3: Suggest a Revised Sequence of Science Ideas in This Lesson |
|---|---|
| | |

| Part 2: Criteria for Sequencing the Science Content Storyline | Yes | No | Comments |
|---|---|---|---|
| a. Is the storyline closely matched to the main learning goal? | | | |
| b. Is the progression of science ideas clearly laid out (i.e., a clear beginning, middle, and end)? | | | |
| c. Are there any gaps or holes in the flow of science ideas? | | | |
| d. Is the storyline cluttered with too many ideas, distracting ideas, or "orphan" ideas (ideas that are mentioned but aren't central to the storyline)? | | | |
| e. Are ideas scientifically accurate? | | | |
| f. Are activities closely matched and linked to the science ideas in the storyline? | | | |
| g. Will the lesson activities engage students in thinking about the main learning goal and supporting science ideas (versus just doing the activity)? | | | |
| h. Are there markers, such as focus questions, linking statements, summary statements, or highlighted statements, that help tie the science content storyline together? | | | |
| i. Will the storyline be visible and make sense to students? | | | |

**Part 3:** Make suggestions for revising the sequence. (*Record in right column of chart on previous page.*)

## Strategies to Create a Coherent Science Content Storyline

## STeLLA Strategy F:
## Make Explicit Links between Science Ideas and Activities

Most good stories move smoothly from one paragraph, event, or chapter to the next. Similarly, a science lesson with a strong science content storyline should be a connected thread of content-related activities and talk leading from the focus question or goal statement through a linked flow of events and science ideas to the conclusion or final summary. Activities that students carry out should be explicitly linked to the content storyline so the science ideas are made visible to students before, during, and after completing an activity and get students thinking about the science ideas (not just the procedures). Therefore, each main activity in a lesson should have a setup, a way of focusing students on the science ideas during the activity, and a follow-up with explicit links to the science content storyline.

### Using Science Ideas before the Activity

***Setup for the activity makes explicit links to science ideas.*** Many times, teachers get so caught up making sure students understand the procedures for carrying out an activity, they forget to engage them in talking about the *purpose* of the activity as it relates to the main science idea (learning goal) of the lesson. It's important that students have a chance to consider the activity in terms of what science ideas they will learn and how those ideas connect to the developing storyline. In planning to teach, consider how you will set up each activity so it requires students to think or make predictions about the science ideas related to the activity.

### Using Science Ideas during the Activity

***The activity is designed so that it requires students to make links between the activity and the science ideas.*** The activity is structured in a way that requires students to think about the science ideas in order to complete the task successfully. Many times, students can successfully finish a task by simply following procedures without thinking about the science ideas embedded within the activity. In the following chart are examples of activities that are structured in ways that do and do not require students to make links between an activity and the science ideas. In planning to teach, design the activity so that students are required to think about science ideas while they're carrying out the activity.

### Using Science Ideas after the Activity

***Follow-up to the activity focuses on linking the activity with science ideas and the science content storyline.*** After each activity, students' attention should be focused on the ways in which the activity contributes to the science content storyline. In a follow-up to the activity, students go beyond simply describing their observations and results to thinking about how the activity relates to the science ideas and the focus question of the lesson. The following chart shows examples that help students understand the purpose of an activity as it relates to the science ideas. In planning to teach, leave time after each main activity to engage students in thinking about the ideas related to the activity.

To make sure you are explicitly linking a science idea and an activity, ask yourself the following questions:

- Am I (or the students) stating a science idea (in a complete sentence) and indicating how that idea is related to the activity students will do, are doing, or have done?

  AND/OR

- Can I clearly identify the science idea (in a complete sentence) I expect students to think about before, during, and after an activity? Can *students* identify the science idea?

**Examples of Activities That Are Explicitly Linked/Not Linked to Science Ideas**

***About Matter, Molecules, and the Water Cycle***

| | Setup for the Activity | During the Activity | Follow-Up to the Activity |
|---|---|---|---|
| **Activity and Science Ideas ARE NOT EXPLICITLY LINKED** | "Yesterday we talked about water evaporating. Today we're going to do another water activity. This time it will be about clouds. Let me tell you how to set up this investigation."<br><br>*[The focus is on the activity, not the science ideas.]* | Students follow worksheet directions to make a "cloud in a bottle." They draw pictures to show what they observe in their bottles.<br><br>*[The focus is on the activity, not the science ideas.]* | The teacher asks a few students to share their observations of the cloud bottles. The students then clean up, and the teacher states, "Today we learned about clouds. Tomorrow we'll learn about the whole water cycle, which includes clouds."<br><br>*[Links topics but not complete-sentence ideas.]* |
| **Activity and Science Ideas ARE EXPLICITLY LINKED** | "As you do this activity, I want you to think about how it helps answer our focus question, *Can you make water disappear?* What do you think will happen when we boil water in this beaker? Will the water disappear?"<br><br>Students offer their predictions, including ideas about boiling, evaporation, and steam.<br><br>*[Students are engaged in thinking about science ideas, not just procedures.]* | Students observe water boiling in a clear beaker and discuss the process of the water "disappearing," including the steam that appears as the water boils. The teacher introduces the term *evaporation* and explains that water in its gaseous state is not visible to the naked eye. The teacher asks students to work in their groups and write what they think happened to the water. "Did the water really disappear?"<br><br>*[Students are engaged in thinking about the science ideas related to their observations.]* | The teacher reminds students of the water-molecules diagrams from the previous lesson and asks, "How can thinking about water molecules help us understand what happens to liquid water when it's heated? What does evaporation have to do with the molecules of water?"<br><br>*[The teacher challenges students to use ideas about molecular motion to explain their observations.]* |

***About Food Webs***

| | Setup for the Activity | During the Activity | Follow-Up to the Activity |
|---|---|---|---|
| **Activity and Science Ideas ARE NOT EXPLICITLY LINKED** | "Remember last week when we put pieces of bread in baggies? Today we're going to observe our bread."<br>*[The focus is only on the activity, not the science ideas.]* | The teacher distributes the baggies with the molding bread. Students observe their bread and draw and label pictures of the bread.<br>*[Students aren't challenged to think about science ideas or questions related to their observations.]* | *Sharing out:* Five students show and explain their drawings.<br>*[Students share their observations, not their ideas about what is happening and why.]* |
| **Activity and Science Ideas ARE EXPLICITLY LINKED** | "Last week we put pieces of bread in baggies. Today we'll look at the bread and think about our focus question, *What causes things to rot?*"<br>*[Students are engaged in thinking about science ideas related to rotting, not just procedures.]* | The teacher distributes the baggies with the molding bread. "As you observe the bread, think and talk about our focus question, *What causes things to rot?"*<br>In small groups, students discuss the following questions and draw/write about them:<br>• What is happening to the bread?<br>• What do you think is causing it to rot?<br>*[Students are engaged in thinking about explanations and science ideas related to their observations.]* | *Whole-class discussion:* "How can you explain the rotting that is happening inside the baggies? What is your evidence?"<br>Following the discussion, the teacher distributes a short reading about how mold and bacteria consume wastes and dead matter and recycle matter to producers. She challenges students to find new ideas in the reading about what causes things to rot.<br>Afterward, students share new ideas from the reading to answer the focus question.<br>*[Students are engaged in linking new ideas to their observations. The teacher makes explicit links in the summary.]* |

## Strategies to Create a Coherent Science Content Storyline

## Analysis Guide F:
## Making Explicit Links between Science Ideas and Activities

**Part 1**

| | |
|---|---|
| Activity Description | |
| Main Learning Goal and/or Focus Question | |
| Supporting Science Ideas Intended to Be Developed through the Activity Setup, the Activity Itself, and the Activity Follow-Up<br><br>(*Number Each Idea.*) | |

**Part 2**

| **Criteria for Explicit Links between Science Ideas and Activity** | **Analysis of Explicit Links between Science Ideas and Activity** | | |
|---|---|---|---|
| **1. Setup for the Activity** | **Yes** | **No** | **Your Analysis of Links in the Setup** |
| a. Are students prompted to think or write about the focus question or goal statement?<br>b. Are explicit links made between science ideas and the activity?<br>c. Does the setup help students understand why they're doing the activity (e.g., what ideas they will learn from it)? | | | |

<table>
<tr><th colspan="1">Criteria for Explicit Links between<br>Science Ideas and Activity</th><th colspan="3">Analysis of Explicit Links<br>between Science Ideas and Activity</th></tr>
<tr><td>2. During the Activity</td><td>Yes</td><td>No</td><td>Your Analysis of Links during the Activity</td></tr>
<tr><td>a. Do students think about science ideas during the activity?<br>(Consider: Do students use ideas, or are they focused on procedures?)<br>b. Do students know they’re expected to connect science ideas with what they’re doing in the activity?<br>(Consider: Does the activity or the teacher help students connect science ideas to what they’re doing?)</td><td></td><td></td><td></td></tr>
<tr><td>3. Follow-Up to the Activity</td><td>Yes</td><td>No</td><td>Your Analysis of Links in the Follow-Up</td></tr>
<tr><td>a. Are science ideas explicitly linked to the activity in the follow-up? If so, indicate what the teacher does or what the students do to link ideas with the activity.<br>b. Are students involved in making links between the science ideas and the activity?</td><td></td><td></td><td></td></tr>
</table>

**Part 3:** Are the linked science ideas well matched to the main learning goal and/or focus question of the lesson? Explain your reasoning.

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## Strategies to Create a Coherent Science Content Storyline

### STeLLA Strategy G: Link Science Ideas to Other Science Ideas

Although each lesson should focus on one main learning goal, students will develop deeper understandings of the learning goal if they comprehend how it's built from and connected to other supporting science ideas and concepts. Any science ideas introduced in a lesson should be clearly and explicitly linked to the main learning goal and should help develop (and not distract from) the science content storyline. In addition, there should be a strong science content storyline *across* lessons. The links between science ideas introduced in one lesson and those in the next lesson should be made visible to students. High-quality links between science ideas have the following features:

- Two (or more) science ideas are being linked. You should be able to state each idea being linked in a complete sentence.
- The link is between ideas, not ideas to activities or activities to activities.
- The ideas being linked are closely matched to the main learning goal.
- The link is clear, explicit, and comprehensible to students.
- The link is scientifically accurate.
- The teacher and/or the students can make the link between ideas.

Following are the different kinds of links that will help build a strong science content storyline within and across lessons.

**Links to Previous and Next Lessons**

Each lesson begins with links to science ideas and concepts (not just to activities!) developed in previous lessons. This can be done by referring back to the science content storyline being developed and/or to focus questions addressed in previous lessons. Similarly, the lesson might end with some hint of how the science-content ideas in today's lesson might be further developed in the next or future lessons.

**Examples of Linking Ideas across Lessons**

***Beginning of lesson on the water cycle:*** Our unit question is "How does water change in the world around us?" Yesterday we learned water can change from a liquid to a gas in the air, where we can no longer see it. Today we'll continue our exploration of how water changes and consider whether that water in the air can ever reappear. If so, how does that happen? If not, why not?

***End of lesson on food webs:*** Today we learned what happens to "dead stuff." We learned that decomposers use wastes and dead organisms as food and leave behind tiny bits of matter such as minerals, carbon dioxide, and water. Tomorrow we'll revisit our discussion of what happens to the "dead stuff" and see if we can use our new knowledge to address the question, "Why are decomposers important in food webs?"

### Links between Supporting Ideas and the Main Learning Goal

Supporting ideas and specialized terminology should be clearly linked to the main learning goal. The teacher sometimes does this linking. For example, the teacher might use a visual representation, such as a diagram or a concept map, to clarify the relationships among ideas.

However, science-learning research suggests that students will develop deeper understandings if they're challenged to make the connections themselves, with careful probing and guidance from the teacher. For example, students could construct simple concept maps to explain the relationships among key science ideas. Then the teacher could link this activity to the main learning goal and use students' efforts to assess and address missing links in their understandings.

Teaching and learning research also suggests that students will find specialized terminology more comprehensible if they first experience a phenomenon and come to understand in everyday words the basic ideas related to it. Then later they can attach scientific terminology to an idea or experience they already hold, and the teacher can link the idea or experience to the main learning goal. For example, students first observe water forming on the outside of a cold glass of ice water, and the teacher encourages them to think about where that water came from. What caused it to form? After working with this phenomenon, students are told that scientists call this process *condensation*. At this point, the word has some meaning—students have an experience to connect to the word. Teaching condensation before the experience will simply be a word to memorize that has little meaning. Although it's sometimes helpful to front-load, or preteach, vocabulary for English language learners, in *science* teaching, it's more meaningful for students to experience the concept first and then learn the specialized vocabulary.

### Links to the Focus Question/Goal Statement

The focus question or goal statement can be used as a conceptual organizer throughout the lesson and in the synthesize/summarize activity at the end of the lesson. Each idea that is addressed can be linked to the focus question. For example, consider a lesson where students are exploring the question, *What is food for plants?* The teacher elicits student ideas and finds out that many students think water is food for plants. Next, students are given a definition of food as "a substance that provides energy for living things." As they read various food and beverage labels, they find out that water has no Calories, which is a measure of food energy. The teacher links these new ideas back to the focus question, "So, do these ideas about food, energy, and water give us any new ideas about our focus question, *What is food for plants? Is water food for plants?*"

In another example, consider a lesson where students are exploring the question, *Why can water exist in three forms—liquid, solid, or gas?* In the lesson, students watch a computer activity that simulates how the motion of water molecules changes when water gains and loses heat energy. The teacher then challenges students to describe the connections between heat energy and molecular motion. She then links these ideas back to the focus question: "So do these observations of molecular motion give us any new ideas about our focus question, *Why can water exist in three forms—liquid, solid, or gas?*"

To make sure you're making a link between one science idea and another, ask yourself these questions:

- Am I making a statement that connects two (or more) science ideas? Can I clearly identify the ideas being connected in complete sentences (not just topics)?

  AND/OR

- Am I engaging students in finding and making connections between two (or more) science ideas? Can I clearly identify in complete sentences (not just topics) the ideas I expect students to connect? Can *students themselves* identify the ideas?

## Strategies to Create a Coherent Science Content Storyline

## Analysis Guide G:
## Linking Science Ideas to Other Science Ideas

Main learning goal and/or focus question: ______________________________________________

_____________________________________________________________________________

_____________________________________________________________________________

**Part 1:** Where do you see links made between one science idea and another science idea? Write time codes in the gray header row of the chart below. Then analyze the links by answering the five questions in the chart.

***Is the link between science ideas a high-quality link?***

| Criteria for Linking Science Ideas to Other Science Ideas | Link 1<br>Time: | Link 2<br>Time: | Link 3<br>Time: | Link 4<br>Time: |
|---|---|---|---|---|
| 1. Are two (or more) complete science ideas being linked together (or is the link only at a topic or activity level)? | | | | |
| 2. Are the science ideas being linked well matched to the main learning goal? | | | | |
| 3. Is the link clear and comprehensible to students (or is it unclear or too vague)? | | | | |
| 4. Is the link scientifically accurate? | | | | |
| 5. Is the link likely to help students develop a coherent science content storyline? | | | | |

**Part 2:** How can the weak links be strengthened?

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**Part 3:** What additional links could be added? Where should they be added?

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## Strategies to Create a Coherent Science Content Storyline

### STeLLA Strategy H:
### Highlight Key Science Ideas and Focus Question Throughout

The science content storyline is easier to follow if the main learning goal, supporting science ideas, and flow of events are highlighted at key points during the lesson.

Highlighting actions include

- referring back to the focus question throughout the lesson;
- writing key science ideas on the board, a transparency, or chart paper;
- telling students, “This is a key science idea”;
- having students write key science ideas in their notebooks;
- providing visual representations that highlight key science ideas;
- revisiting key science ideas multiple times in a lesson; and
- summarizing at key transition points in the lesson.

The teacher can highlight key science ideas in a variety of ways, such as asking about them repeatedly through review questions, having students say or repeat important ideas, pointing out that a particular science idea is very important, and guiding students to underline or highlight key sentences on a worksheet.

Students can also take the lead in highlighting key science ideas. They might be asked to identify the key ideas from a reading or respond to a question about the most important science ideas discussed in the lesson thus far. For example, the teacher might stop at key transition points in the lesson to highlight the ideas developed so far:

- “So what have we learned so far about water molecules and how they behave in different states of matter?”
- “What ideas do we have so far about how decomposers help provide matter for plants?”

## Strategies to Create a Coherent Science Content Storyline

## Analysis Guide H:
## Highlighting Key Science Ideas and Focus Question

Main learning goal or focus question: ______________________________________________

____________________________________________________________________________

____________________________________________________________________________

**Part 1:** Where do you see examples of highlighting key science ideas? Write video time codes in the gray header row of the chart below. Then analyze the quality of the highlighting by answering the five questions in the chart.

***Is this highlight of high quality?***

| Criteria for Highlighting Key Science Ideas | Highlight A<br>Time: | Highlight B<br>Time: | Highlight C<br>Time: |
|---|---|---|---|
| 1. Does the teacher mark a key science idea (not just a topic or activity) as important? | | | |
| 2. Is the highlighted science idea(s) matched to the main learning goal? | | | |
| 3. Are students likely to notice and understand that this idea is important? | | | |
| 4. Is the highlighted idea scientifically accurate? | | | |
| 5. Is the highlighting done in a way that is likely to help students construct a coherent science content storyline? | | | |

**Part 2:** How can these highlights be strengthened?

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____________________________________________________________________________

____________________________________________________________________________

**Part 3:** What additional highlights could be added? Where?

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

## Strategies to Create a Coherent Science Content Storyline

## STeLLA Strategy I:
## Summarize Key Science Ideas

The science content storyline needs to be tied together at the end of a lesson. A summary statement is one way to make connections between the science ideas and activities addressed in the lesson and highlight how they support the main learning goal of the lesson.

A summary statement typically occurs near the end of the lesson. The teacher can state it as a strategy for returning students' attention to the focus question or goal statement and for clarifying the intended learning goals. Student Thinking Lens strategy 7 focuses on engaging students in the synthesizing and summarizing process. This is usually more supportive of student learning, but if time is short, a teacher summary is better than no summary at all.

Challenging learning goals are rarely neatly addressed and wrapped up in one lesson. Sometimes a lesson summary may be a statement of where we are today and what we still have to learn before we can answer our focus question.

In developing summarizing statements and activities, consider the following questions:

1. Does the summary focus on conceptual understandings and not just a list of facts or activities?
2. Do the science ideas in the summary match the main learning goal and the focus question or goal statement? By thinking about the focus question, main learning goal, and summary together, teachers make sure the science content storyline is tied together for students by the end of each lesson.
3. Is the summary statement/activity scientifically accurate?
4. Are students engaged in making sense of the summary statement?

**Examples of Summarizing Key Science Ideas**

***About Matter, Molecules, and the Water Cycle***

| | |
|---|---|
| T: | Today we learned about condensation. The important idea I want you to think about from this lesson is that water-vapor molecules we can't see in the air will slow down and join together to form liquid water when they lose heat energy (cool). This idea is going to be really important tomorrow when we think about how water moves on Earth. Who can repeat part of what I just said? |
| Emily: | Condensation is when water vapor turns back into liquid water. |
| T: | That's one key idea from today. Can anyone elaborate on that? |
| Arturo: | Condensation happens when the water-vapor molecules are cooled. |
| T: | Good, you added that molecules and the loss of heat energy (cooling) are involved. Another elaboration on this idea? |

| | |
|---|---|
| Shanda: | Yeah, the water-vapor molecules slow down and come closer together when they're cooled. |
| T: | OK, all of these are key ideas from today's lesson. Condensation occurs when gaseous water-vapor molecules are cooled, slow down, and join together to form liquid water. |

***About Food Webs***

| | |
|---|---|
| T: | Let's look at the key ideas I've written on the board during our lesson today: "Energy moves from one organism to another in a food web—from producers to consumers to decomposers. Energy moves in a one-way path—it's passed along and used by living things. It can't be reused or recycled." Tomorrow we're going to compare these ideas with how matter moves in food webs. So let's make sure we have these key ideas about energy in mind. Who can state one of our key ideas about energy in food webs? |
| Emily: | Energy moves from one organism to another in a food web. |
| T: | That's one key idea from today. Can anyone elaborate on that? |
| Arturo: | Energy moves from the Sun to plants to consumers to decomposers. |
| T: | Good. Another elaboration on this idea? |
| Shanda: | Energy doesn't go in a cycle; like it can't go from decomposers back to plants. |
| T: | OK, I think we've captured all of these key ideas: Energy moves from producers to consumers to decomposers in food webs. As it is passed along, organisms use it to help them live. This energy can't be reused or recycled. |

(*Note:* The analysis guide for strategy I appears earlier in this document. See Analysis Guides B and I on page 51.)

 

## Summary of STeLLA Science Content Storyline Lens Strategies

| | Strategy | Purpose |
|---|---|---|
| Develop the Science Content Storyline **during Planning** | Identify one main learning goal. | To identify the complete science concept you want students to learn *(for teacher)* |
| | Set the purpose with a focus question or goal statement. | To provide a focus for the lesson that keeps attention on the main learning goal *(for students)* |
| | Select activities that are matched to the learning goal. | To select activities that help students deepen their understandings of the main learning goal |
| | Select content representations and models matched to the learning goal and engage students in their use. | To select content representations and models that help students deepen their understandings of the main learning goal |
| | Sequence key science ideas and activities appropriately. | To develop a science content storyline that will make sense to students |
| | Summarize key science ideas. | To plan how the storyline will be tied together |

| | Strategy | When in the Lesson | Purpose |
|---|---|---|---|
| Develop the Science Content Storyline **during Teaching**<br><br>***NOTE:*** *Planning is a critical step in being prepared to revisit, highlight, and link.* | Set the purpose with a focus question or goal statement. | At the beginning and highlight throughout | To focus students' attention on the purpose of the lesson |
| | Make explicit links between science ideas and activities. | • Before each activity<br>• During each activity<br>• After each activity | To make the science content storyline visible to students<br><br>To engage students in thinking about the science ideas related to the activities |
| | Link science ideas to other science ideas. | • Beginning: Link to ideas from previous lessons<br>• During lesson: As appropriate<br>• End: Link ideas developed during the lesson and in previous lessons; foreshadow next lesson | To make the storyline visible to students<br><br>To engage students in thinking about the connections among science ideas |
| | Highlight key science ideas and focus question throughout. | Multiple times during the lesson | To make the main learning goal and supporting ideas more visible to students |
| | Summarize key science ideas. | End of the lesson | To tie the storyline together |

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