Strategies for Effective Science Teaching:

The Student Thinking and Science Content Storyline Lenses

Grade 6

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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Contents

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 to 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 that sunlight hits Earth's surface at different angles.
- **Evidence:** At video segment 16:54, the teacher comes over and asks Miriam to explain her model of the Earth-Sun system. Miriam says that the Sun's rays are hotter at certain times of year, and that's why parts of Earth are warmer in the summer.

Analysis Basic 3: Look More Than Once

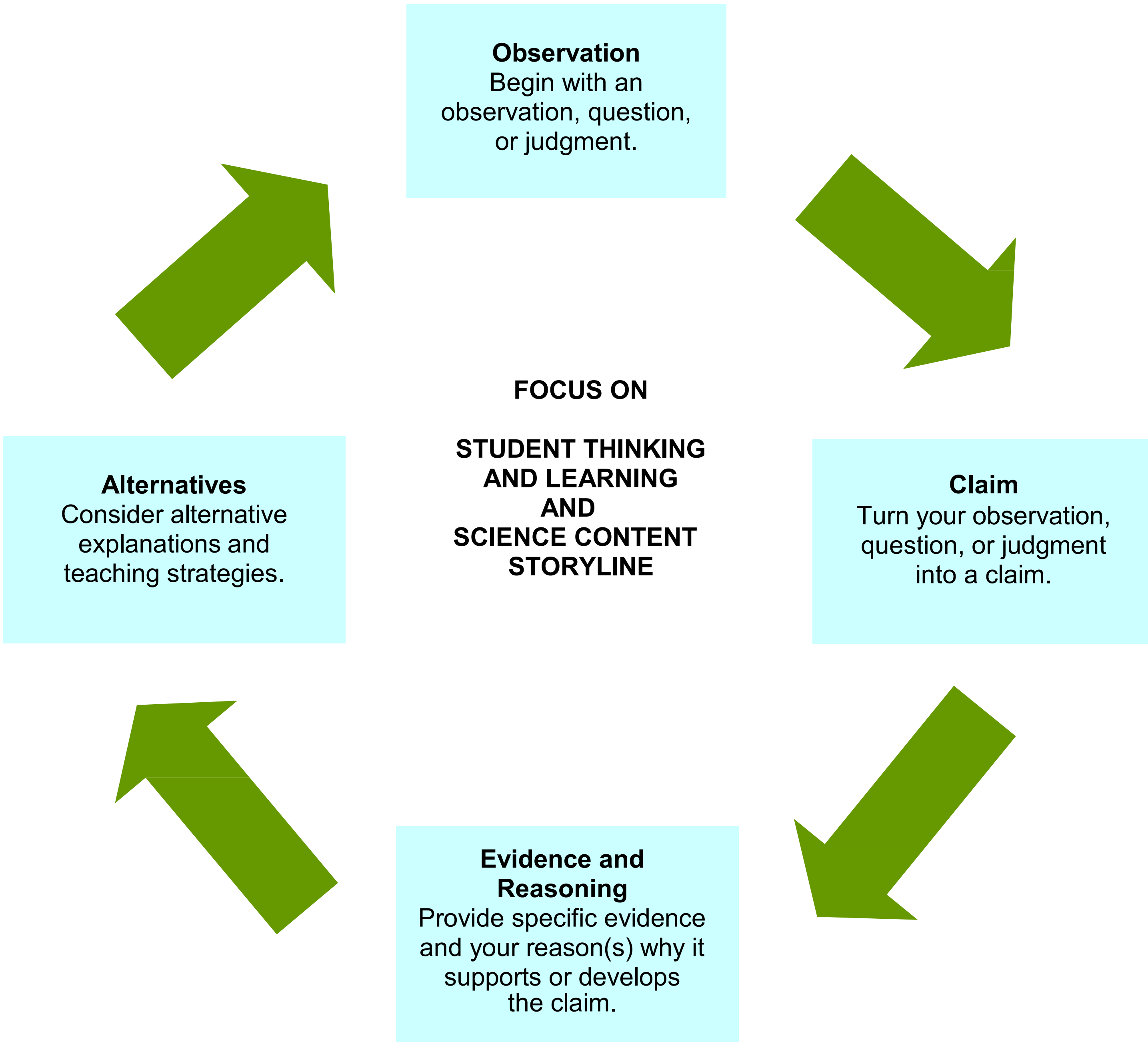
Video recording enables us to look at a teaching episode over and over. Take advantage of this opportunity. To deepen your learning from analyzing classroom videos, look at them more than once. Studying transcripts is a powerful way of revisiting a lesson clip. Let go of your everyday *entertainment 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 Begin with an observation, question, or judgment.	• Do the students really understand this activity?
Claim Turn your observation, question, or judgment into a specific claim.	• I don't think students understand that this activity is intended to demonstrate that the tilt of Earth as it orbits around the Sun causes seasons.
Evidence and Reasoning Provide specific evidence and reason(s) why it supports or develops the claim.	• When Charlie is trying to model Earth's orbit, he wants to tilt Earth back and forth on its axis to show how seasons might happen. In the video, he says, "The tilt leans toward the Sun when we have summer and away from the Sun during winter" as he is tilting the model of Earth back and forth.
Alternatives Consider alternative explanations and teaching strategies.	• Charlie understands that Earth's tilt has something to do with seasonal variations, but he hasn't conceptualized how the tilt continually stays the same even though Earth's position in relation to the Sun changes during its orbit. Have Charlie use a model of Earth's orbit around the Sun to demonstrate how the tilt can stay the same and still produce seasons.

Analysis of Science Content Storyline

Lesson Analysis Stage	Example
Observation Begin with an observation, question, or judgment.	• I think students are confused about why they're doing this simulation.
Claim Turn your observation, question, or judgment into a specific claim.	• Prior to this activity, students need to understand that the simulation will help them answer the focus question, *What happens when traits get passed from parents to children?*
Evidence and Reasoning Provide specific evidence and reason(s) why it supports or develops the claim.	• In the video, a student asks, "Why are we looking at all these different organisms?" Because students are confused about the purpose of the activity, they aren't focusing on the traits and how they appear in parents and offspring. At segment 25:07, another student says, "Ahh, your cats are so cute, but our fruit flies are just creepy." This also indicates that students are focused on the different types of organisms instead of the observable traits in parents and offspring.
Alternatives Consider alternative explanations or teaching strategies.	• The teacher could set up the activity by having students predict what will happen when parents' with specific trait variations have offspring (or mate/breed). That would help focus students' attention on seeing whether their predictions are correct.

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 (climate, genetics),
- a student activity ("Students are making concept maps."),
- 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 uneven heating on Earth and what scientists have learned about it.

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 the Sun's Effect on Climate

a. Earth is tilted at an angle of approximately 23.5 degrees in its orbital plane. *(Fact)*

b. Sunlight falls more intensely on different parts of Earth during the year. *(Accurate statement and observable pattern)*

c. Seasons result from variations in the angle and intensity of the Sun's energy hitting Earth's surface, which is due to the curved surface of Earth, the consistent tilt of Earth on its axis, Earth's daily rotation, and Earth's yearly orbit around the Sun. *(Concept)*

d. Earth's orbit around the Sun, which is nearly circular, can be predicted based on Newton's theory of gravity. *(Theory)*

Examples of Science Ideas about Genetics

a. A dominant trait appears in offspring even if only one dominant allele is present, while a recessive trait appears only if two recessive alleles are present. *(Terminology)*

b. If an individual who is homozygous for a dominant trait mates with an individual with a recessive trait, all of the offspring will have the dominant trait. *(Accurate statement and observable pattern)*

c. In sexually reproducing organisms, individuals inherit one allele for each gene from each parent, resulting in many possible combinations of alleles and genes. This explains the broad range of trait variations observed in a population. *(Concept)*

d. The proportion of offspring with dominant and recessive traits from a particular set of parents can be predicted using Mendel's principles of inheritance. *(Theory)*

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 students study the Sun's effect on climate or trait variations in genetic inheritance, how are they already thinking about why seasons change or why there is so much trait variation among individuals? Why do they think it's hotter in some places on Earth than others? What are their personal theories about Earth's relationship to the Sun? What do they think is the impact of Earth's tilted axis on seasons? Can they even imagine a tilted Earth? Why do they think some offspring look like their parents and some don't? What are their theories about how traits are passed from parents to offspring?

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 a trait is?" most students will have nothing to contribute. In contrast, many students will be able to respond to a question that asks, "Why do you think children look like their parents?" 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 the Sun's Effect on Climate

- Why doesn't summer last all year long?
- In Michigan, it often snows in December, but in Australia, it's usually hot in December. How can that be?
- If you hike to the top of a mountain, will it be hotter or colder than where you started? Why do you think so?

About Genetics

- Why don't any of the dachshund puppies have long hair like their father? Why did they all have short hair like their mother?
- Both of the parent pea plants had yellow seeds, but some of the offspring had green seeds. How do you think this happened?

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 the Sun's Effect on Climate

Context: Students analyze data showing different temperatures at various locations on Earth.

S: At the equator, it's really hot.

T: If the area near the equator is usually hot, what can you say about the rest of Earth's surface? (*Challenge*)

S: I think it will be cooler.

T: Can you tell me more about your thinking? (*Probe*)

S: It will get colder the farther you are from the equator.

T: What do you mean by "the farther you are from the equator"? Can you show me on the globe? (*Probe*)

S: Well, I guess it will be cooler up here above the equator, but it will be pretty hot below the equator. So I think it depends on whether you're north or south of the equator.

T: So can you tell me how you came to that conclusion? (*Probe*)

About Genetics

Context: Students look at a long-haired dog and a short-haired dog and consider what their puppies would look like.

S: Maybe there will be some long hair and some short hair.

T: So are you thinking some puppies will have long hair and some will have short hair? (*Probe*)

S: No, I think the puppies will have medium hair—in between long and short hair.

T: Can you tell me more about why you think the puppies will have medium-length hair? (*Probe*)

S: Because kids usually have fifty-fifty of each parent's traits.

T: What do you mean by "fifty-fifty of each parent's traits"? (*Probe*)

S: Like, kids are sort of a mix of their parents' traits.

T: So do you think that each trait in the offspring is a blending of the parents' traits? (*Probe*)

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 the Sun’s Effect on Climate	**About Genetics**
T: Is it hotter in the summer because we’re closer to the Sun at that time of year? S: Yes. T: Really? What were we just talking about that plays an important role in causing seasons on Earth? S: Uhhhhhh … T: Is Earth always straight up and down? S: Oh! No, it’s tilted.	T: So if two parents mate, and both of them have one dominant and one recessive allele, will half of the offspring have the dominant trait and half have the recessive trait? S: Yes. T: Are you sure? Look at the Punnett square. These three cells show offspring with which trait? S: The dominant trait. T: And this cell shows offspring with … S: The recessive trait.

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 the Sun's Effect on Climate

Context: Students observe what happens when light shines on a model of Earth when Earth's axis is at 0 degrees—straight up and down with no tilt.

T: Based on your investigation, would there be seasons in the Northern Hemisphere? (*Challenge*)

S: I don't think so because there is no tilt.

T: Can you explain why Earth's tilt is necessary for there to be seasons? (*Challenge*)

S: We saw that the Sun's rays hit Earth's surface at different angles at different times of year, and so if the angles change, then the seasons change.

T: So how does Earth's tilt affect the incoming rays of sunlight if you're standing at the equator? (*Challenge*)

S: Well, the equator gets direct rays all the time, so it doesn't change.

T: You say the equator gets direct rays all the time. So that doesn't change at all during the year? (*Probe*)

S: Well, it might change a little, because sometimes the most direct light is at the Tropic of Cancer.

T: What do you mean by "the most direct light"? (*Probe*)

S: During our summer, the most direct light—the rays that are most straight on from the Sun— hits the Northern Hemisphere, so it's summer here and winter in the Southern Hemisphere. When it's winter here, then the most straight-on rays of sunlight are hitting the Tropic of Capricorn in the Southern Hemisphere, so it's warmer there.

T: OK. Can you show me with the globe how we have seasons? The rest of you think about what you would do while Henry thinks about it too. (*Challenge*)

S: So, I'd just tilt [the globe] like this.

T: OK, and what season would this represent for the Southern Hemisphere? (*Challenge*)

S: Winter.

T: So what would have to happen for summer to happen in the Southern Hemisphere? (*Challenge*)

S: Earth would have to move.

T: What do you mean by "move"? (*Probe*)

S: Earth would have to move around the Sun. If the tilt stays the same, then the Southern Hemisphere has summer on the opposite side of the globe, like this.

About Genetics

Context: Students complete a simulation for passing alleles for the bill-color trait in fictional "ducko" organisms from parents to first-generation offspring. Then they apply science ideas from this model to butterflies and discuss the wing color that second-generation offspring of Generation 1 butterflies will likely have.

T: One of the organisms we looked at earlier was a butterfly. When orange and white butterflies mated, all of the Generation 1 offspring were orange. Based on our model with the duckos, what will the offspring of the second-generation butterflies look like? (*Challenge*)

S: Some will be orange, and some will be white.

T: Can you explain how this happens? Why are there both orange and white butterflies in Generation 2 when all of their parents were orange? (*Challenge*)

S: Because the Generation 1 parents had one allele for orange wings and one for white wings.

T: Tell me what you mean by "allele." (*Probe*)

S: An allele is a version of a gene—like here, there are alleles for orange wings and white wings.

T: How does this relate to what we've been studying? (*Challenge*)

S: The orange allele is the dominant allele, and the white one is recessive.

T: How do dominant and recessive alleles affect what the butterflies look like? (*Challenge*)

S: The butterflies only need one orange allele to have orange wings because it's dominant. But to have white wings, they need two white alleles because it's recessive.

T: So the Generation 1 parents have orange wings because they have a dominant allele. You said before that the Generation 1 parents had one orange allele and one white allele. Explain how they can have offspring with white wings. (*Challenge*)

S: If both parents give the white allele to the offspring, then the white trait will show up, because there are no dominant orange alleles.

T: How do the numbers of offspring with white wings and orange wings compare? *(Not an elicit, probe, or challenge question; simply asking for an observation)*

S: There are more butterflies with orange wings.

T: Why is that? (*Challenge*)

S: Because there are more ways to make orange wings than white wings.

T: What do you mean by "more ways to make orange wings"? (*Challenge*)

S: The offspring could get a dominant allele from both parents, or they could get a dominant allele from one parent and a recessive allele from the other parent. Both of these make a butterfly with orange wings.

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 the Sun's Effect on Climate

- Students use a flashlight and tray with graph paper to measure changes in the intensity of sunlight based on the angle at which the light hits the tray. They use this information to understand why light hitting a surface at an angle is less concentrated or more spread out (covers more area) than light hitting a surface straight on at a 90-degree angle.
- Students make line graphs of average monthly temperatures in different cities around the world to see how temperature patterns may vary in cities at the same latitude.
- Students collect and record data on the speed at which soil and water heat up and cool down. Then they compare their results with average temperatures of cities located at similar latitudes that have varying proximity to large bodies of water. This information helps students understand how living near an ocean or in the interior of a continent might influence surface air temperatures.

About Genetics

- Students observe similarities and differences between parents and their offspring, as well as variations between offspring from the same parents. They look for patterns in these observations and brainstorm reasons or explanations for why these patterns might exist.
- Students randomly select instructions for a trait (a gene) from a bag representing the mother's alleles and a bag representing the father's alleles. They record the resulting allele combinations and traits of the offspring. Then they compare the ratio of offspring with different traits generated from the 10 offspring their group created with a predicted ratio of offspring with different traits based on the combination of the parents' alleles shown in a Punnett square. This provides evidence supporting an explanation for the pattern of trait inheritance in the offspring of certain parents.

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.

[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.

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.

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 …*

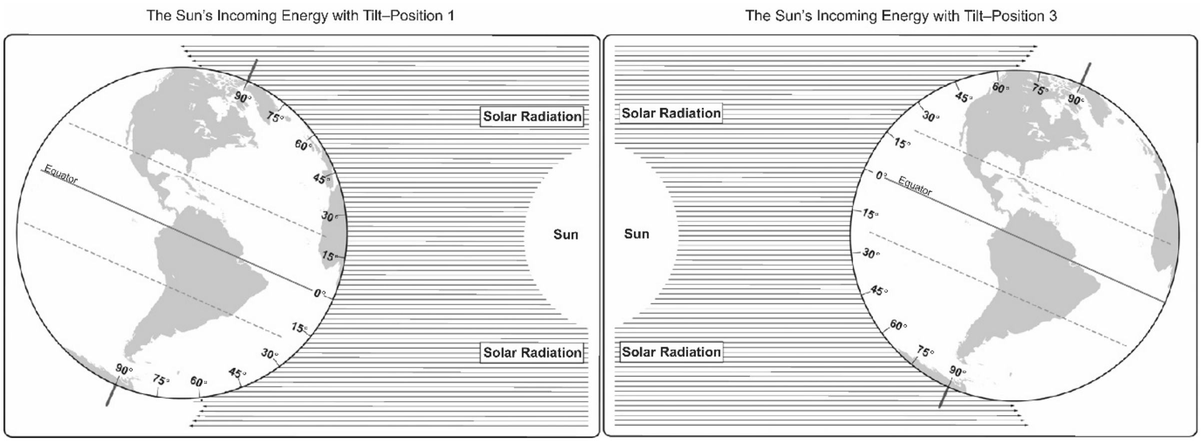
When Is Strategy 5 Used?

- 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 the Sun's Effect on Climate

Context: Students investigate how the tilt of Earth on its axis and its orbit around the Sun affect the amount of solar energy different parts of Earth receive. To complete this investigation, students look at two illustrations of Earth that show latitude lines when Earth's Northern Hemisphere is tilted toward the Sun and when it's tilted away from the Sun. Then they record information from several latitudes on a data table.



Adapted with permission from Dr. Lawrence Woolf, General Atomics Sciences Education Foundation

The handout says, "Count the number of lines of solar radiation hitting Earth at the following latitudes and record the numbers on your data table":

Latitude 60–75° N
Latitude 30–45° N
Latitude 0–15° N
Latitude 0–15° S
Latitude 30–45° S
Latitude 60–75° S

S1: I think it must be summer in the Northern Hemisphere when Earth is in position 1, because the Northern Hemisphere has more lines in each latitude segment. That must mean they're closer together, so I think it's warmer in the Northern Hemisphere in position 1.

S2: I agree, because look at the North Pole. It has a bunch of lines, and in the same latitude near the South Pole, there aren't any lines hitting at all. That means more of the Sun's rays are hitting the northern part of Earth, and the southern part of Earth must be having winter.

S3: The Sun is hitting straight on north of the equator. The day we used the flashlight and tray, we saw that the place that's getting light from the Sun at the 90-degree angle has the most concentrated light. That makes sense because the latitude segment between 15° and 30° N has more lines that anywhere else. I counted them even though that isn't on the data table. All of our reasons seem to point to the same conclusion: Position 1 must be summer in the Northern Hemisphere.

S4: And if I just took all your arguments and applied them to position 3, I would say that it's summer in the Southern Hemisphere in that position.

About Genetics

Context: Students are trying to explain a pattern of inheritance in dachshunds, where one parent has long hair and one parent has short hair. In the first generation, all the puppies have short hair, and none have long hair, but when the first-generation dachshunds were bred with short-haired dogs that had similar parents, some of the second-generation puppies had long hair, and some had short hair. Students are provided with three possible explanations for the pattern and must use observations and logic to argue for one of them:

1. Since all the puppies have short hair, they must have inherited instructions for hair length from only one parent.
2. The puppies inherited information for hair length from both parents. But the instructions for short hair covered up the instructions for long hair.
3. The puppies got instructions for hair length from each parent, so they should have medium-length hair—a blend of short and long hair.

In small groups, students discuss and present arguments to support their ideas.

S1: I want to rule out explanation 3 right away. Look, not a single puppy in Generation 1 or Generation 2 had medium-length hair, so that explanation couldn't possibly be correct.

S2: I agree. But I'm still not sure about explanations 1 and 2. Is it possible that the puppies get instructions for hair length from only one of their parents?

S3: I don't think that's possible either. Explanation 1 works if you're only looking at the first generation. All of the puppies could have gotten the instructions for the length of their fur from the short-haired parent—like the instructions for hair length might have come only from the mom with short hair, and they didn't get anything from the dad. But it isn't possible if you look at the second generation. Both the mom and the dad had short hair. So if you got information for hair length from only one of your parents, it doesn't matter which parent you got it from, it would have to be instructions for short hair.

S2: Oh, I think I see what you're saying. I agree. Explanation 1 doesn't fit what the puppies look like in Generation 2. I guess only explanation 2 fits all of the data from this set of observations.

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 climate?"). 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 the Sun's Effect on Climate

Context: At the end of a series of lessons about the Sun's effect on climate, students write a story about two pen pals, one from the United States and one from Argentina. Their letters compare what those students do, what they wear, and what the weather is like in January and July where they live. Students must also draw one or more pictures showing the positions of the Sun and Earth in January and July that explain the differences in seasons in the United States and Argentina.

The teacher instructs students to locate the following cities or countries on a world map and describe the weather and temperature patterns in each location based on January and July temperature data. Students are also asked to pay special attention to the latitude of each location.

Nome, AK, USA	Rio de Janeiro, Brazil
Portland, OR, USA	Rio Gallegos, Argentina
Charleston, SC, USA	Rothera Point, Antarctica
Hanover, Germany	Paso de Indios, Argentina
Lagos, Nigeria	Beira, Mozambique
Mumbai, India	Jakarta, Indonesia
Guangzhou, China	Sydney Australia

About Genetics

- After an activity in which students use fictional organisms (duckos) to model how alleles are passed from parents with one dominant and one recessive allele to their offspring, they consider evidence about a trait in a real organism. As they observe the appearance of the recessive trait among the offspring, students note that more offspring have the dominant trait than the recessive trait. They apply what they learned from the model to this evidence by identifying the dominant allele and explaining why the parents were able to pass on the recessive trait when they didn't exhibit the trait themselves.

- Students use ideas about how traits are passed from parents to offspring to determine whether a particular trait is dominant or recessive in three generations of a family.

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 Sun's effect on climate, the teacher might have students create a concept map that organizes key science ideas to explain how the Sun is related to Earth's seasonal changes. Or toward the end of the Genetics unit, students might write a story about two cats that exhibit three different traits. In the story, they could present evidence that one of the three traits is determined by genes alone, one is determined by the environment alone, and one is determined by both genetics and the environment.

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 the Sun's Effect on Climate

Context: After learning about Earth's tilt and its impact on seasons, students are asked to use these ideas to create a model of Earth's orbit around the Sun. Using a lightbulb or flashlight (to represent the Sun), a Styrofoam ball (to represent Earth), and a Hula Hoop (to represent the orbit of Earth around the Sun), students show the orbital positions of Earth during the summer, fall, winter, and spring in the Northern Hemisphere. Then they show the orbital positions of

Earth when the Southern Hemisphere is experiencing the four seasons. In the process, students explain why the Northern and Southern Hemispheres experience opposite seasons at the same time of year.

- As students complete each lesson about the Sun's effect on climate, they write in their science notebooks about *one* reason Earth's surface heats unevenly and the results of that uneven heating (where it is hot/warm, where it is cold/cool, and why). Then after the final lesson, students write a paragraph about why temperatures vary on Earth based on their deepening understandings of the uneven heating of Earth's surface.
- At the end of a lesson, the teacher asks each student to think of one sentence that would summarize the most important idea of the lesson. As time allows, the teacher then calls on as many students as possible to share their sentences, with the teacher and other students giving feedback about the quality and accuracy of the summary sentences.
- At the end of a lesson, the teacher asks small groups of three or four students to write the story of Sun's effect on climate. In a round-robin, each student contributes one sentence building off the sentences of other students. Then students revise and sequence the story as needed.

About Genetics

- At the end of a lesson, the teacher provides three sentence starters for students to complete regarding how dachshunds inherit the long- and short-haired trait. Then the teacher asks several students to share how they completed the sentences and encourages others to agree or disagree and explain why.
- At the end of a lesson series on inheritance, students are shown a family pedigree focusing on a trait controlled by a single gene. Students are then asked to write a paragraph tracing a particular trait through the family and describing how a family member in the third generation ended up with the trait. In their paragraph, students must use key vocabulary terms they've learned throughout the unit, such as *trait*, *gene*, *chromosome*, *allele*, *dominant*, and *recessive*.

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. Students in these environments 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

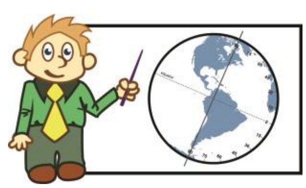
These practices represent a much richer view of scientific activity than the "scientific method," the widely accepted but overly simplistic view of science. The NGSS science practices present a more accurate view of science as focusing on evidence and argument in building and using models and in generating 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.

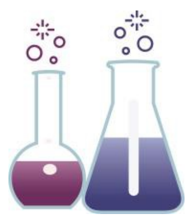
	STeLLA **Communicating in Scientific Ways**	***Next Generation Science Standards*: Science Practices**
1.	Ask why and how questions.	Asking questions
2.	Observe.	Analyzing and interpreting data Using mathematics and computational thinking
3.	Organize data and observations.	
4.	Think of an idea, claim,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

Examples of Ways to Engage Students in Communicating Scientifically

The following Communicating in Scientific Ways chart 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 …? I wonder … Why …? How do they know that …?
2. Observe.		I see … I noticed … I recorded … I measured …
3. Organize data and observations.		I see a pattern … I think we could make a graph … Let's make a chart …
4. Think of an idea, claim, prediction, or model to explain your data and observations.		My idea is … I think that … We could draw a picture to show … I think it looks like this …
5. Give evidence for your idea or claim.		My evidence is … The reason I think that is … 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 … 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 …? What do you mean when you say …? What is your evidence?
8. Agree or disagree with others' ideas.		I agree with _______ because … I disagree with _______ because …
9. Add onto someone else's idea.		I want to piggyback on _____'s idea. 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 … That idea doesn't make sense because … What's their evidence?
12. Suggest an experiment or activity to get more evidence or to answer a new question.		What if we …? We could get better evidence if we …
13. Let your ideas change and grow.		I think I'm changing my idea. 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 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 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 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 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 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., "San Francisco's proximity to water has a moderating effect on its weather" or "The ratio of dominant to recessive traits in Generation 2 offspring is 3:1"). 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 "inheritance of dominant and recessive traits" sounds good on the surface, but what exactly do you want students to understand about inheritance? Will you focus on the idea that each parent contributes one allele to an offspring? Do you want students to understand the difference between a dominant and a recessive trait, or allele? Do you want them to understand why recessive traits can sometimes skip a generation?

A main learning goal IS NOT …

- a topic or phrase (such as seasons, inheritance, dominant and recessive traits).
- an activity (such as examining maps or completing a Punnett square).
- a question (such as “Why do traits appear and disappear across generations?” or “What temperature patterns can you find on Earth at different times of the year?”).
- a performance task or objective (such as “Explain why Earth’s seasons change” or “Describe what you see in this bar graph”).
- a supporting detail, definition, or fact (such as “Earth is tilted at 23.5 degrees” or “All the offspring have the dominant trait”).
- a misconception—a student idea that isn’t scientifically accurate (“Seasons change as the Sun moves” or “All children look like both of their parents”).

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., “the Sun’s effect on climate” or “the effect of genetics on variations between individuals of a species”). 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., model seasons using a lightbulb and a ball, or simulate how alleles pass from parents to offspring), it’s important to keep in mind the essential knowledge you want them to take away from those activities. For example, “modeling seasons on Earth” isn’t considered a main learning goal because it doesn’t clearly state a complete science concept students should learn. In contrast, “together, the tilt of Earth, its orbit around the Sun, and the angle of sunlight hitting Earth at different latitudes cause the surface to heat unevenly and produce seasons” *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
The Sun's Effect On Climate	• Because Earth is a sphere, sunlight hits the curved surface more directly closer to the equator and at increasing angles moving toward the poles. • Earth's consistent tilt toward the North Star produces opposite seasons in the Northern and Southern Hemispheres.	• Why do we have seasons? (*Question*) • Why is it hotter in summer and colder in winter in our state? (*Question*) • Earth's tilt and the seasons (*Topic*) • Comparing temperature and latitude at different times of year (*Activity*) • Uneven heating of Earth and its relationship to seasons (*Not a complete sentence*)
Genetics	• During reproduction, parents' alleles separate and recombine randomly in their offspring. • Understanding how chromosomes (and the genes on them) move allows us to predict patterns of inheritance and the likelihood of certain traits appearing among offspring.	• Why do some traits disappear and reappear across generations? (*Question*) • Making a bar graph to compare the ratio of different phenotypes (*Activity*) • Dominant and recessive traits (*Topic*) • When a parent with two recessive genes for a trait is crossed with a parent with both a dominant and a recessive gene for that trait, the predicted ratio of offspring with each trait will be 1:1. (*Supporting detail or fact*)

Analysis Guide A:
Identifying One Main Learning Goal

State the main learning goal being analyzed: ____

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Criteria for the 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? a. It is worthy of 40 minutes or more being spent on it. b. It has important connections to other science ideas and can be used to explain a variety of phenomena. 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: ______________________________________

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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

<table>
<tr><td rowspan="4">**The Sun's Effect On Climate**</td><td colspan="4">**Main learning goal:** The consistent tilt of Earth on its axis and its orbit around the Sun cause uneven heating of the surface, resulting in opposite seasons in the Northern and Southern Hemispheres.</td></tr>
<tr><td></td><td>**1. NOT Closely Linked to the Main Learning Goal**</td><td>**2. NOT Understandable and Engaging to Students (Uses Scientific Terminology)**</td><td>**3. Is Linked to the Learning Goal and Is Understandable and Engaging to Students**</td></tr>
<tr><td>**Focus Question**</td><td>Why is it warmer today than it was yesterday?</td><td>How do the consistent tilt of Earth on its axis and its orbit around the Sun contribute to the uneven heating of Earth's surface?</td><td>Why is it winter in the northern United States when it's summer in Argentina?</td></tr>
<tr><td>**Goal Statement**</td><td>By the end of today's lesson, you'll be able to explain how the Sun affects our daily temperatures.</td><td>Today we'll learn how Earth's tilt and orbit lead to uneven heating of the planet at different times of the year.</td><td>Today we're going to learn why it's summer in the Northern Hemisphere when it's winter in the Southern Hemisphere.</td></tr>
</table>

<table>
<tr><td rowspan="4">**Genetics**</td><td colspan="4">**Main learning goal:** Organisms that reproduce sexually get one allele for a gene from each parent, making it possible for offspring to have different allele combinations and, thus, different traits.</td></tr>
<tr><td></td><td>**1. NOT Closely Linked to the Main Learning Goal**</td><td>**2. NOT Understandable and Engaging to Students (Uses Scientific Terminology)**</td><td>**3. Is Linked to the Learning Goal and Is Understandable and Engaging to Students**</td></tr>
<tr><td>**Focus Question**</td><td>How do genes affect the traits an organism exhibits?</td><td>Why do sexually reproducing organisms have different allele combinations and exhibit different traits?</td><td>Why do some traits disappear and reappear across generations?
OR
Why don't offspring always look like their parents?</td></tr>
<tr><td>**Goal Statement**</td><td>Today we're going to learn how genes affect traits.</td><td>By the end of the lesson, you'll be able to explain how the alleles in sexually reproducing organisms get passed to offspring in different combinations.</td><td>Today we're going to learn why some traits disappear and reappear across generations.
OR
Today we're going to learn why offspring don't always look like their parents.</td></tr>
</table>

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 the Sun's Effect on Climate

Learning goal: Average temperatures on Earth's surface vary according to latitude.	
Activities NOT CLOSELY MATCHED to the Learning Goal	**Activities CLOSELY MATCHED to the Learning Goal**
Students graph temperature data over the year from their hometown. Each student makes a bar graph to show the data visually. Teams then discuss the patterns they observe in the data.	Students record temperature data for five different latitudes in January and July. Each student makes a bar graph showing the data visually. Teams then discuss the patterns they observe in the data.

About Genetics

Learning goal: Parents who have two different forms of some traits have offspring that look like just one of the parents.	
Activities NOT CLOSELY MATCHED to Learning Goal	**Activities CLOSELY MATCHED to Learning Goal**
Students examine the results of crossing pea plants that have yellow seeds. They discover that the offspring produce either yellow or green seeds in a 3:1 ratio.	Students participate in a simulation in which they play the roles of parents who have two different forms of a trait for a variety of organisms. They record the traits of the resulting offspring and discover that for all of these organisms, the offspring look just like one of the parents.

Strategies to Create a Coherent Science Content Storyline

Analysis Guide C:
Selecting Activities Matched to the Learning Goal

List the main learning goal: ____

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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 **(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.

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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., Earth's tilt or orbit around the Sun; chromosomes passing from parents to offspring). 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 first identify seasonal temperature patterns and then use a globe and lightbulb to explore their initial ideas about how the movement of Earth around the Sun might explain those patterns. Students can also deepen their understandings by *using* scientists' models to make sense of phenomena they observe. For example, they can contrast their movement of a globe around a lightbulb with images from a text or online simulations to identify the similarities and differences between their initial ideas and ideas commonly accepted in the scientific community.

Examples of Representations on the Sun's Effect on Climate

- The light from a flashlight hitting a tray at a 90-degree angle and a 45-degree angle (to represent the Sun's rays hitting Earth's surface at the equator and closer to the poles, respectively)
- An illustration of the Sun's rays reaching a tilted Earth (with labels)
- A model of the relationship between the Sun and Earth using a lightbulb and a ball

Examples of Representations on Genetics

- A histogram showing variations in the length of mice's tails
- A Punnett square showing the possible genotypes offspring may inherit from their parents
- A model contrasting *genotype* (the combination of alleles) and *phenotype* (a description of traits) using gene cards and Lego "duckos"

Sample Analyses of Content Representations

Example 1a. The Sun's Effect on Climate: Using the Criteria in Selecting Content Representations

Main learning goal: Because Earth consistently tilts on its axis as it moves around the Sun, sunlight hits the surface at various angles at different times of the year. This is why seasonal changes happen in many parts of the world.

Content representation: Students use a flashlight to represent the Sun and a blow-up globe to represent Earth. They shine light on the globe and move the globe around the "Sun" to simulate summer and winter in the United States.

Analyzing the Sun-and-Earth Representation

Is this model scientifically accurate? One major inaccuracy of the model is the size of the "Sun" (the flashlight) in comparison to "Earth" (the globe). In reality, the Sun is much larger than Earth. As students use the model, they see the Sun shining on just a small part of the globe at any given time. The accuracy of the representation also depends on how students move the globe around the Sun: Do they enact an approximate circular orbit? Do they keep the tilt of "Earth" steady as it moves around the Sun? (A common student error is to shift the tilt of the globe as it travels around the Sun (the light) so that the globe is always pointing away from the Sun.)

Is this model likely to make sense to young students? This is a challenging model for students to manipulate, but it can still be quite effective with upper-elementary students. Here are some problems: First, it's easy for students to hold the globe and flashlight in ways that support incorrect explanations. For example, students often move the flashlight (Sun) to simulate summer in the Northern Hemisphere even when the Northern Hemisphere is pointing away from the Sun. Second, students will move the globe to make it fit their conceptions (rather than sticking with an accurate orbit). For example, if students are trying to simulate summer in the Southern Hemisphere when the Sun is shining on the Northern Hemisphere, they will simply move the globe higher so the flashlight is shining on the Southern Hemisphere. A third common problem is not tilting the globe consistently in the same direction throughout its orbit around the Sun.

Might the model introduce or reinforce misconceptions about the Sun and seasons? Yes, because students can manipulate the globe and flashlight to make the model fit with their own preconceptions. Of special concern is students' insistence that distance between Earth and the Sun is the main cause of seasons.

Does the model distract students from the main learning goal with too many details or new terms? No. This model closely matches the learning goal if caution is used to avoid common misconceptions.

Suggestions for improving the model:

- Tape short straws to each pole to help students pay attention to the axis and the direction of the globe's tilt.
- Use a stationary, bare lightbulb instead of a flashlight to represent the Sun.
- Use a mini globe to better represent the scale of Earth compared to the Sun.
- Instead of using a real light, use a huge yellow ball and a small globe for the whole-class discussion and demonstration. Have one student use yellow string to represent the Sun's rays hitting Earth at different angles based on latitude.

Example 1b. The Sun's Effect on Climate: Engaging students in *Using* Content Representations

As students use the Earth-Sun model, you can support their thinking and learning in the following ways:

- Emphasize to students that the scale of this model is quite misleading. Show them photos or a different representation to help them envision the huge size of the Sun compared to Earth. Also help them understand the great distance between the Sun and Earth.
- Structure the task so that students have to stop and identify the direction of Earth's tilt at opposite ends in its orbit around the Sun.
- Structure the task so that students must draw a diagram of their model to show summer and winter in North America.
- Have each student in the small group take a turn moving the globe around the "Sun" and explaining when and why it's summer and winter in North America.
- Have a whole-class discussion and demonstration of the model to help students clarify and solidify their understandings.
- Challenge students to revisit the model to show summer and winter in Argentina.

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

Main learning goal: Organisms that reproduce sexually receive one allele for a gene from each parent, making it possible for offspring to have different allele combinations and, thus, different traits.

Content representation to be analyzed: Students play the role of red-billed or orange-billed "ducko" parents. Each student has a bag with two gene cards that represent the parents' alleles for the bill-color trait. The gene cards state either "Give the ducko a RED bill" or "IF there is no allele with instructions for a red bill, give the ducko an ORANGE bill." In the first round, half of the students have a bag with two red-bill gene cards and half have a bag with two orange-bill gene cards. Red-billed and orange-billed parents are paired, and each contributes one gene card (allele) to an offspring gene bag. Then students build the appropriate Lego offspring following the directions on the gene cards. All of the offspring will have one red-bill gene card and one orange-bill gene card. They will all show the trait of red bills because of the dominant red-bill gene.

In the second round, the first-generation duckos become the parents for a second generation of offspring. Again, each student randomly selects one gene card (allele) to contribute to the second generation offspring. Depending on which gene cards are selected, the offspring will receive two red-bill gene cards (alleles), one red-bill gene card and one orange-bill gene card, or two orange-bill gene cards. In the first two cases, the offspring have red bills; in the last case, they have orange bills.

Analyzing the Ducko Simulation

Is this model scientifically accurate? There are two main inaccuracies in this model: (1) the "duckos" are fictional organisms, and (2) alleles aren't written instructions on a card but actual sequences of nucleotide bases in DNA specifying the proteins that determine a trait. Another error will occur if students look at the gene cards and select the one they want to contribute in the second round of the simulation. In reality, alleles move randomly into the sex cells, which in turn are combined randomly to create offspring. If students select the gene cards they want to combine, they're likely to choose a combination that gives them one red-billed and one orange-billed ducko. This will result in ratios of red-billed to orange-billed offspring that aren't consistent with actual ratios of dominant and recessive traits in nature.

Is the model closely matched to the main learning goal of the lesson? In the first round of the simulation, all offspring have the same genotype: one red-billed allele and one orange-billed allele. This result doesn't match the main learning goal about offspring inheriting different combinations of alleles. It does, however, set up the situation for second-generation offspring to inherit different combinations of alleles and express different traits. Consequently, students discover the main learning goal of the lesson in the second round of the simulation.

Is this model likely to make sense to young students? Yes, this model can help students understand abstract genetic concepts, such as alleles and genotypes, by giving them physical representations: The gene cards represent alleles as the instructions for a trait, and the bags containing two gene cards representing an individual's genotype (combinations of alleles).

Might the model introduce or reinforce misconceptions? Because the model doesn't include the copying and distribution of chromosomes in the production of gametes, students may be confused about the likelihood of offspring inheriting particular alleles from their parents. For example, students may think that a parent with two different alleles will give one to the first offspring and the other to the second offspring instead of recognizing that there is an equal chance of either allele being passed on to each offspring.

Does the model distract students from the main idea with too many details or new terms? Students are likely to be very engaged in the model because it gives them an opportunity to play with the Legos while they're building the duckos. This may distract them from the main idea. Also, the accuracy of the model depends on following the activity instructions carefully, and yet students may find them a bit confusing. Finally, the model affords an opportunity for teachers to introduce and use the terms *allele*, *genotype*, *dominant*, and *recessive*. Each of these terms represents a challenging concept for students to understand. To mitigate these problems, teachers should consider the following:

- Allow students an opportunity to build duckos from the Legos for a few minutes before actually beginning the activity.
- As you review the instructions with the students, model the process they should follow.
- Consider carefully when to introduce the genetics terms. For example, introduce *allele* and *genotype* following the first round of the simulation, so you can refer to the two different gene cards as alleles and the two alleles in a bag as the genotype of an individual. This will give students concrete images for these abstract ideas. Similarly, don't introduce the terms *dominant* and *recessive* until after the second round when you're discussing the

- different allele combinations found in the second-generation offspring. At that point, it will make sense to students that the red-bill allele is dominant and the orange-bill allele is recessive because the offspring that have a red-bill allele always have the red-bill trait.

Example 2b. Genetics: Engaging Students in *Using* the Ducko Simulation

In addition to presenting students with the ducko simulation, a teacher could ask students to perform the following tasks:

- Interpret the simulation and come up with some generalizations: What is the simulation showing about how alleles are passed from parents to offspring and are recombined in the offspring?
- Calculate these ratios:
    - The ratio of red-billed to orange-billed second-generation offspring from the class data
    - The ratio of the three different genotypes among the second-generation offspring from the class data
- Suggest a way to modify the simulation to show offspring from parents with different genotypes.
- Discuss this question with their group: What parental genotypes would result in equal numbers of red- billed and orange-billed offspring?

Strategies to Create a Coherent Science Content Storyline

Analysis Guide D:
Selecting and Using Content Representations

Main learning goal: ____

____

Description of content representation: ____

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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

____

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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 unit about genetics in a 5th- or 6th-grade classroom might address the driving question, "How do we explain differences among individuals?" Addressing this question would involve investigations of the role of dominant and recessive genes in determining traits, how those genes are passed from parents to offspring, and what influences the expression of those genes. 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., traits, inheritance, climate, Earth's rotation) 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 [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 why colder temperatures occur at higher elevations. Then the teacher might have students use these ideas as they create a narrative describing a trip to the mountains that explains the changes in temperature they experience.

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 Sun’s Effect on Climate: 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 seasons.” Also, the ideas about temperature, sunlight, and changing seasons aren’t connected to one another in any logical sequence. The lesson starts with a focus on uneven heating, but the idea of uneven heating isn’t reflected in the lesson activities.

Weak Sequence of Sun-Climate Science Ideas	Weak Sequence of Sun-Climate Activities
Earth has different temperatures, and they change throughout the year. That’s why we wear different clothes at different times of year.	Today we’re going to learn about why Earth’s surface has different temperatures. Why do you think we wear coats in the winter and shorts in the summer?
Earth has different seasons.	*Activity 1:* Students compare photos of different seasons and describe what each season is like.
Temperatures change throughout the year.	*Activity 2:* Students plot a temperature line graph of their hometown and discuss the temperature patterns they see on the graph.
Earth is tilted and orbits the Sun.	*Activity 3:* Students look at a diagram of a tilted Earth as it orbits the Sun.
	Lesson ending: What did you learn today about the uneven heating of Earth?

Genetics: Weak Example of Sequencing

This lesson example is weak because the main learning goal is unclear. Students are supposed to be learning about genetics, but it isn't clear what they're supposed to learn about how traits are inherited. The first activity focuses on identifying variations among different types of dogs. This introduces ideas that aren't directly focused on trait *inheritance* and might be distracting to students. The second activity focuses on the idea that genes provide instructions for traits, and that some alleles of a gene are dominant, while others are recessive. But it does nothing to support the development of the idea that an individual receives one copy of a gene from each parent, and the appearance of a trait varies because individuals may receive the same or different alleles of the gene from each parent. In sum, the activities don't closely match the main learning goal, and the main learning goal is vague.

Weak Sequence of Genetics Science Ideas	Weak Sequence of Genetics Activities
	Today we're going to learn about how traits are inherited.
Individuals within a group of organisms show variations in their traits. These variations could be due to genetic factors or environmental factors.	*Activity 1:* Students look at pictures of various breeds of dogs. Each small group lists the differences they observe and then discuss the following questions: • What ideas do you have to explain the differences you observed? • Can you place your ideas into two different categories? Students recognize that their ideas are related either to something the dogs inherited from their parents or to something the dogs' owners have provided or not provided for the dogs.
Genes provide the instructions that determine the traits an individual exhibits. Sexually reproducing organisms inherit one copy of a gene from each parent, and thus, they have two copies of every gene. Different versions of a gene are called *alleles*. These different alleles result in variations of a trait. Alleles that show the trait associated with them when only one copy is present are called *dominant alleles*. Alleles that show their trait only when two copies are present are called *recessive alleles*.	*Activity 2:* Students participate in a simulation in which they obtain a bag with two of the same allele for hair length in dachshunds. Representing the alleles are cards with instructions for short or long hair. Students follow the instructions to draw a picture of a dog that exhibits the specified hair-length trait. Then students obtain a bag with two different alleles (instructions) for hair length and follow the instructions to draw a picture of a dog that exhibits the dominant short-hair trait. Finally students answer the following questions in their science notebooks: • Which hair-length allele is dominant? Why? Why is the other allele recessive?

Weak Sequence of Genetics Science Ideas	Weak Sequence of Genetics Activities
	• Which two alleles for hair length did the dog have in the second simulation? • Did the dog have short or long hair? Why? • Is there one or more combinations of alleles that would give the dog the same hair length? If so, what is/are those combinations?
	Lesson ending: What did you learn today about why dogs look different from one another?

The Sun's Effect on Climate: Strong Example of Sequencing

In this lesson, there is a clear main learning goal that explains how the angle at which sunlight hits Earth's surface causes uneven heating. 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 Sun-Climate Science Ideas	Strong Sequence of Sun-Climate Activities
Temperatures on Earth tend to vary according to latitude.	The teacher revisits the unit central question, *Why are some places on Earth hotter than others at different times of the year?* and links with the previous lesson in which students learned that places near the equator have warmer temperatures than those farther away.
	Focus question: "Why are places close to the equator hotter than places farther from it?" Write student ideas on the board. Set students up for an activity to measure the intensity of light based on the incoming angle of the Sun's rays.
When light hits a surface straight on (or perpendicular to it), the energy is more concentrated over a smaller area. When light hits a surface indirectly (at a less direct angle), the energy is more spread out (less concentrated).	In pairs, students simulate the Sun's rays using a flashlight and a tray with graph paper on it. They measure the concentration of light when the flashlight shines directly on (perpendicular to) the tray, and when the flashlight shines on the tray at a less direct angle. Then they count the number of squares of graph paper the flashlight shined on to determine the surface area it covered.

Strong Sequence of Sun-Climate Science Ideas	Strong Sequence of Sun-Climate Activities
Sunlight shines most directly near the equator, so it provides more heat per unit area (one square on the graph paper). When sunlight hits at less direct angles toward the poles, it's more spread out and doesn't provide as much heat per unit area.	Students compare the data they collected from the tray and flashlight model to a globe. The teacher explains and highlights key science ideas using a globe.
The angle of sunlight hitting Earth's surface affects heating. When the angle of sunlight is more direct, the light energy is more intense, and Earth's surface will get warmer. When sunlight strikes Earth's surface less directly moving from the equator toward the poles, the light energy is less concentrated, and the surface doesn't warm up as much.	The teacher summarizes key science ideas from the lesson. The teacher links to previous and future lessons: Yesterday we learned that there are different temperatures at different latitudes. Today we learned that because Earth is a sphere, sunlight hits Earth's surface at different angles. As a result, places closer to the equator are warmer than places closer to the poles. Tomorrow we'll think about how the places that have the most-direct sunlight might change as Earth orbits the Sun.

Genetics: Strong Example of Sequencing

In this lesson, there is a clear main learning goal. Students learn that a gene provides instructions for a trait, and different versions of the same gene are called *alleles*. Different alleles result in trait variations among offspring. The lesson begins and ends with a focus question that is well matched to the main learning goal: *How does a gene determine what trait an individual has?* 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 Genetics Science Ideas	Strong Sequence of Genetics Activities
	Focus question: "How does a gene determine which trait an individual inherits?" The teacher projects pictures of short-haired and long-haired dachshunds and their puppies, all of which have short hair. Then the teacher reminds students of their earlier decision that hair length in the dachshunds was a genetic trait.

Strong Sequence of Genetics Science Ideas	**Strong Sequence of Genetics Activities**
	Elicit students' initial ideas: What is your initial idea of what a gene is? Discuss these questions with your team: • Where are genes found? • How are genes related to traits? What do genes have to do with the differences observed among individuals?
Genes are the instructions for a trait. Sexually reproducing organisms have two copies of each gene.	The teacher shows students two fictional duck-like organisms called *duckos*. One has a red bill, and the other has an orange bill. The teacher explains that a gene determines the bill-color trait. The teacher has two student volunteers come to the front of the classroom and distributes a bag to each student containing cards that represent bill-color genes. One bag contains genes for the red-billed trait, and one contains genes for the orange-billed trait. Each bag represents the nucleus of a cell in each organism that contains the genes. The volunteers draw from their bags, pulling out two bill-color cards. The cards from the Red-billed Parent Nucleus bag have instructions to give the ducko a red bill. The cards from the Orange-billed Parent Nucleus bag say, "IF there is no allele with instructions for a red bill, give the ducko an ORANGE bill." Students then answer the following questions: • What chromosomes and genes do you find in each nucleus that determine bill color? • What alleles for bill color do each of these duckos have? Now do you want to change your answers to any of the questions that we began with in this lesson?

Strong Sequence of Genetics Science Ideas	Strong Sequence of Genetics Activities
Dominant alleles provide instructions for a trait variation that will show up no matter what other allele it’s paired with. Recessive alleles provide instructions for a trait variation that shows up only if it is paired with another recessive allele.	The teacher shows the results of a red-billed parent mating with an orange-billed parent: All of the offspring have red bills. Students are challenged to use what they’ve learned about genes to explain this result: • Why don’t any of the offspring have orange bills? • Is the allele for orange bills gone? • How would you describe the relationship between the allele for red bills and the allele for orange bills? The teacher introduces words that describe the relationship between the alleles: *dominant* and *recessive*.
Genes are the instructions for traits that individuals inherit. Alleles of a gene give slightly different instructions, resulting in trait variations. Only one dominant allele is necessary for a trait variation to show up, but two recessive alleles are necessary for a trait variation to show up.	*Lesson summary:* What did we learn today about our focus question, “How does a gene determine what trait an individual inherits?” Use the words *gene*, *allele*, *dominant*, and *recessive* to explain why all of the dachshund puppies from long- and short-haired parents had short hair.

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 this 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 the Sun's Effect on Climate

	Setup for the Activity	**During the Activity**	**Follow-Up to the Activity**
Activity and Science Ideas ARE NOT EXPLICITLY LINKED	"Today in our unit about the Sun's energy, we're going to use this worksheet to create a graph showing Earth's temperatures." *[The focus is on the activity, not the science ideas.]*	"Let me show you how to transfer the data about temperatures at different latitudes to make your graph." The teacher provides an example on the board; then students complete their graphs as the teacher circulates among the groups. *[The focus is on the activity, not the science ideas.]*	Students compare their graphs to see whether they look the same or different. The teacher asks some students to redo their graphs using examples from other students. *[There is no discussion of science ideas related to the activity.]*
Activity and Science Ideas ARE EXPLICITLY LINKED	"As we get ready to graph our data comparing latitude and average temperatures, I want you to think about how the data relate to our focus question, *What patterns can we find related to temperatures at different latitudes on Earth?*" *[Students are engaged in thinking about science ideas, not just procedures.]*	Students create bar graphs using data on latitude and average temperatures from locations around the world in the same month. Then they look for patterns in the data. The teacher uses a globe to help students find the latitude that corresponds to their temperature data. Students notice that temperatures are warmer closer to the equator and cooler closer to the poles. *[Students are engaged in thinking about the science ideas related to their observations.]*	Students work in small groups to explain why they think temperatures are generally warmer closer to the equator. They use a model of Earth marked with latitude lines to help them with their explanations. *[The teacher challenges students to use ideas about molecular motion to explain their observations.]*

About Genetics

	Setup for the Activity	During the Activity	Follow-Up to the Activity
Activity and Science Ideas ARE NOT EXPLICITLY LINKED	"Yesterday we looked at the second-generation offspring of first-generation offspring that had one dominant and one recessive allele for a trait. Today we're going to calculate the ratio of dominant to recessive traits among the second-generation offspring." *[The focus is only on the activity, not the science ideas.]*	The teacher models how to calculate the ratio of dominant to recessive traits among the offspring. Then the teacher displays a chart listing traits in a variety of organisms and the numbers of second-generation offspring with the dominant and recessive variations of the trait. Students copy the chart, calculate the ratios, and add them to the chart. *[Students aren't challenged to think about science ideas or questions related to their observations.]*	*Sharing out:* Different students share the ratios they calculated for each row, and the class checks for agreement. The teacher asks students what they notice about the ratios, and they note that all of them are about 3:1. *[Students share the results of their calculations, not their ideas about what is happening to bring about a ratio of approximately 3:1.]*
Activity and Science Ideas ARE EXPLICITLY LINKED	"Yesterday we used a Punnett square to see how alleles pass from parents to offspring. Before that, we looked at Generation 2 offspring and noticed that the recessive trait shows up again in the offspring, but a lot more of them have the dominant trait than the recessive trait. "So today you're going to use the Punnett-square model to explain the numbers of Generation 2 offspring with variations of the trait. Our focus question is *Why do most offspring have the dominant trait?*" *[Students are engaged in thinking about how to explain an observation,*	The teacher gives each small group a different organism and trait along with the genotypes of the parents (both of which have one dominant and one recessive allele). Small groups work on these tasks: • Fill in the Punnett square describing how the parents' alleles are recombined and distributed to Generation 2 offspring. • Determine the expected ratio of dominant to recessive traits among the offspring. The teacher distributes to each group actual data for the number of offspring with the dominant and recessive	The teacher reconvenes the class and reminds students of the focus question, *Why do most offspring have the dominant trait?* Then the teacher pairs up small groups and challenges them to use their Punnett-square models and data to answer the focus question. After students finish their explanations, the teacher summarizes: "Offspring with parents that both have one dominant and one recessive allele receive one allele from each of them. They could receive a dominant allele from both parents, a dominant allele from their mother and a recessive allele from their father, or a recessive allele from their mother and a dominant allele from their father. "In all three cases, the

	Setup for the Activity	During the Activity	Follow-Up to the Activity
	not just using a procedure or calculating ratios.]	traits. Students are challenged to determine whether the results support their inheritance model for dominant and recessive traits in their group's organism. To determine this, students do the following: • Calculate the actual ratio of dominant to recessive traits found in Generation 2 offspring. • Explain how these results support or don't support their Punnett-square models. *[Students are engaged in thinking about the science ideas related to their data.]*	offspring have the dominant trait. The last possibility is that the offspring could receive a recessive allele from each parent. In this case, the offspring would exhibit the recessive trait. So we expect a 3:1 ratio of dominant to recessive traits among the offspring." *[Students are engaged in linking their ideas about inheritance to their observations. The teacher makes explicit links to these ideas 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 (*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? b. Are explicit links made between science ideas and the activity? c. Does the setup help students understand why they're doing the activity (e.g., what ideas they will learn from it)?			

Criteria for Explicit Links between Science Ideas and Activity	Analysis of Explicit Links between Science Ideas and Activity		
2. During the Activity	**Yes**	**No**	**Your Analysis of Links during the Activity**
a. Do students think about science ideas during the activity? *(Consider: Do students use ideas, or are they focused on procedures?)* b. Do students know they're expected to connect science ideas with what they're doing in the activity? (*Consider: Does the activity or the teacher help students connect science ideas to what they're doing?*)			
3. Follow-Up to the Activity	**Yes**	**No**	**Your Analysis of Links in the Follow-Up**
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. b. Are *students* involved in making links between the science ideas and the activity?			

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 genetics: Our central question for these lessons is *How can we explain differences among individuals?* Yesterday we observed that offspring from long-haired and short-haired parents all have short hair. Today we'll continue our exploration of this difference in the hair-length trait by exploring if and when the missing long-hair trait shows up again.

End of lesson: Today we learned that the missing trait may show up again in offspring from parents who don't necessarily exhibit the trait themselves. Tomorrow we'll read about chromosomes and how they're related to genes. Then we'll revisit what we discovered today about offspring who exhibit a trait that doesn't show up in their parents, and we'll use our new ideas about chromosomes and genes to explain how this happens.

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, at the beginning of a lesson, students might compare temperature data related to latitude on Earth's surface and realize that temperatures are warmer at latitudes closer to the equator and cooler at latitudes farther away from the equator. After students demonstrate an understanding of this concept, the teacher introduces the phrase "uneven heating of Earth's surface." 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 other ideas help us make sense of the way traits are inherited?* In the lesson, they review what they've learned about trait inheritance in dachshunds and then read a summary of the results of Walter Sutton's research on chromosomes. The teacher helps students relate the trait-inheritance findings to the movement of chromosomes when eggs and sperm are made and then unite to form a new individual. The teacher then links these ideas back to the focus question by asking, "How did Sutton's ideas about chromosomes help us answer our focus question, *What other ideas help us make sense of the way traits are inherited?*"

In another example, consider a lesson where students are exploring the question, *Why do some places at the same latitude have different temperature patterns?* In the lesson, students graph temperature data for three different US cities located at about the same latitude. Students think about why the temperature graphs look different for each city even though the cities are at about the same latitude. Students use a physical map of the United States to describe the regional geography of each city, and the teacher helps them understand that even though the latitude of these cities is about the same, the geography is very different. One city is close to the mountains, another is near the ocean, and the third has no proximity to either one. The teacher links these ideas back to the lesson focus question, *Why do some places at the same latitude have different temperature patterns?*

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: ____

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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 Time:	Link 2 Time:	Link 3 Time:	Link 4 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:

- “What does this activity with the lightbulb representing the Sun and the Styrofoam ball representing Earth tell us about our focus question? Let’s write down the main things we’ve learned so far.”
- “What have we learned so far about why a trait from one parent doesn’t appear in the offspring?”

Strategies to Create a Coherent Science Content Storyline

Analysis Guide H:
Highlighting Key Science Ideas and Focus Question

Main learning goal or focus question: ____

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Part 1: Where do you see examples of highlighting key science ideas? Write 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 Time:	Highlight B Time:	Highlight C 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?

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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 the Sun's Effect on Climate

T:	Which of these statements do you think is the best summary of what we learned today? Which is the best answer to the focus question? Remember our focus question is *Why does the equator have the highest average temperatures?* Here are your choices: 1. It's hotter at the equator because Earth bulges out at the equator, which makes it closer to the Sun so it gets more heat. 2. It's hotter near the equator because the Sun's rays hit Earth's surface in a concentrated way, but further north and south of the equator, the Sun's rays hit at a less direct angle because of Earth's curved surface. 3. It's hotter near the equator because of the tilt of Earth, which puts the equator closer to the Sun. 4. It's hotter near the equator because of all three reasons: the distance of Earth from the Sun, Earth's tilt, and the angle at which the Sun's rays hit Earth's curved surface.

T:	Think about this for a minute.
	Student think time.
T:	Now on the count of three, give me a show of hands. Hold up one finger if you think the best answer is number 1, hold up two fingers for number 2, hold up three fingers for number 3, and four fingers for number 4.
	The class discusses any discrepancies in the responses.
T:	So to summarize what we learned today, the equator is hotter than other parts of Earth because sunlight hits the surface at the equator in a more direct, concentrated way. North and south of the equator, sunlight hits at a less direct angle because of Earth's curved surface. This spreads the heat out over a bigger area, so it doesn't get as hot.

About Genetics

T:	In today's lesson, we considered patterns we see in the inheritance of traits. For example, we found that the offspring of parents who have different variations of a trait don't have an in-between variation of the trait. Tomorrow we're going to look at chromosomes inside the nucleus of a cell and compare their behavior with what we've observed about the inheritance of traits. So let's make sure we have in our minds the key ideas about what we've learned about trait inheritance. Who can state one of the key ideas?
Emily:	The offspring of parents who have two different traits can have the same trait as just one of the parents.
T:	That's one key idea from today. Can anyone elaborate on that?
Arturo:	The trait that shows up in the offspring is called the *dominant trait*.
T:	Good. Another elaboration on this idea?
Shanda:	The other trait—the one that doesn't show up—is the *recessive trait*.
T:	That's good too. Can anyone share a key idea about the offspring in the next or second generation—the children of the first generation of offspring you just talked about?
Michael:	Most of the offspring in the next generation have the dominant trait, but some of them show the recessive trait.
T:	OK, I think we've captured all of the key ideas: An offspring's trait isn't a blend between the two trait variations the parents have. Instead, the offspring exhibit just one trait, which we call the *dominant trait*. The *recessive trait* shows up again in the second generation of offspring, but fewer of these offspring show the recessive trait than the dominant trait.

(*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** ***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 • During each activity • After each activity	To make the science content storyline visible to students 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 • During lesson: As appropriate • End: Link ideas developed during the lesson and in previous lessons; foreshadow next lesson	To make the storyline visible to students 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

References

American Association for the Advancement of Science (AAAS). (2001, 2007). *Atlas of science literacy* (Vols. 1–2). Washington, DC: AAAS Project 2061.

Krajcik, J., & Reiser, B. J. (2004). *IQWST: Investigating and questioning our world through science and technology*. Evanston, IL: Northwestern University.

National Research Council (NRC). (2008). *Ready, set, science! Putting research to work in K–8 science classrooms*. Washington, DC: National Academies Press.

National Research Council (NRC). (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.

NGSS Lead States. (2013). *Next generation science standards: For states, by state*s. Washington, DC: The National Academies Press.

Roth, K. J., Druker, S. L., Garnier, H. E., Lemmens, M., Chen, C., Kawanaka, T., … Gallimore, R. (2006). *Teaching science in five countries: Results from the TIMSS 1999 video study*. Washington, DC: National Center for Education Statistics. Retrieved from http://nces.ed.gov/timss.