

OVERVIEW

This activity provides three sets of cards that can be used to reflect on the nature and dimensions of science. The cards are based on the three dimensions of science learning in the Next Generation Science Standards (NGSS) and [A Framework for K-12 Science Education](#): Science and Engineering Practices (SEP), Crosscutting Concepts (CCC), and Disciplinary Core Ideas (DCI). Regardless of which standards you are using, focusing on these dimensions helps support students' learning, increases their engagement in metacognition, and illustrates how all scientists and engineers work.

This document contains multiple resources for using the cards with students, including the following (click links to go directly to each section):

- [background](#) on the dimensions of science learning in the cards
- general [teaching tips](#) for this resource
- suggested [procedures](#) for using the cards, including lists of questions for formative assessments

Additional information related to pedagogy and implementation can be found on [this resource's webpage](#), including suggested audience, estimated time, and curriculum connections.

KEY CONCEPTS

- There are multiple ways to explore a phenomenon and experience the nature of science.
- Dimensions of science include science practices, interdisciplinary (“crosscutting”) connections, and discipline-specific core ideas.
- Reflecting on one’s learning process (metacognition) can help strengthen one’s learning overall.

STUDENT LEARNING TARGETS

- Identify and implement the various ways that one experiences the nature of science, depending on the phenomenon observed.
- Reflect on the science practices used to make sense of a phenomenon.
- Describe interdisciplinary (“crosscutting”) concepts that act as lenses through which a phenomenon is investigated.
- Determine the core ideas under which an observed phenomenon is situated.

PRIOR KNOWLEDGE

Depending on which cards or card sets are used, students may need to be familiar with:

- certain science practices (e.g., using models, data, systems, scientific argumentation, etc.)
- certain overarching biology concepts (e.g., energy and matter, ecosystems, genetic variation, biodiversity, etc.)

MATERIALS

- sets of “Student Cards” (SEP, CCC, DCI) for each student or student group

BACKGROUND

In the United States, most state standards for K–12 science education are based on [A Framework for K-12 Science Education](#): a set of research-based recommendations released in 2012. This framework set expectations for what students should know and be able to do in different grades, which build coherently across grade levels. State standards based on the *Framework* include the **Next Generation Science Standards (NGSS)** and other, often similar, variations.

Within the *Framework*, there are three dimensions of science learning: Science and Engineering Practices (SEP), Crosscutting Concepts (CCC), and Disciplinary Core Ideas (DCI). Integrating these three dimensions through **three-dimensional learning** helps students build a more cohesive understanding of science and better reflects how science is done in the real world. Each dimension corresponds to one of the three “Student Cards” sets for this activity (SEP, CCC, or DCI). An overview of the dimensions is provided below; refer to the cards and/or the [NGSS website](#) for more information.

Science and engineering practices (SEP) are practices that scientists use to investigate the world, and that engineers use to design and build systems. There are eight SEPs:

- **SEP1:** Asking Questions and Defining Problems
- **SEP2:** Developing and Using Models
- **SEP3:** Planning and Carrying Out Investigations
- **SEP4:** Analyzing and Interpreting Data
- **SEP5:** Using Mathematics and Computational Thinking
- **SEP6:** Constructing Explanations and Designing Solutions
- **SEP7:** Engaging in Argument from Evidence
- **SEP8:** Obtaining, Evaluating, and Communicating Information

Crosscutting concepts (CCC) are concepts that apply across all domains of science and thus connect different domains. There are seven CCCs:

- **CCC1:** Patterns
- **CCC2:** Cause and Effect
- **CCC3:** Scale, Proportion, and Quantity
- **CCC4:** Systems and System Models
- **CCC5:** Energy and Matter
- **CCC6:** Structure and Function
- **CCC7:** Stability and Change

Disciplinary core ideas (DCI) are key ideas in a specific discipline of science. This activity uses the DCIs for life science (LS), which consist of four core ideas (LS1–4), each with several components (e.g., A–D):

- **LS1:** From Molecules to Organisms: Structures and Processes
 - **LS1.A:** Structure and Function
 - **LS1.B:** Growth and Development of Organisms
 - **LS1.C:** Organization for Matter and Energy Flow in Organisms
 - **LS1.D:** Information Processing
- **LS2:** Ecosystems: Interactions, Energy, and Dynamics
 - **LS2.A:** Interdependent Relationships in Ecosystems
 - **LS2.B:** Cycles of Matter and Energy Transfer in Ecosystems

- **LS2.C:** Ecosystem Dynamics, Functioning, and Resilience
- **LS2.D:** Social Interactions and Group Behavior
- **LS3:** Heredity: Inheritance and Variation of Traits
 - **LS3.A:** Inheritance of Traits
 - **LS3.B:** Variation of Traits
- **LS4:** Biological Evolution: Unity and Diversity
 - **LS4.A:** Evidence of Common Ancestry and Diversity
 - **LS4.B:** Natural Selection
 - **LS4.C:** Adaptation
 - **LS4.D:** Biodiversity and Humans

TEACHING TIPS

- Print or electronically share files for the cards from [this resource's webpage](#).
 - A PDF file is provided as a printable option. You can cut out the cards and laminate them for repeated use.
 - Individual card images (JPGs) are provided in the “Card Images” ZIP file. You can use a virtual whiteboarding or collaboration software (e.g., Google Jamboard, Miro) in which students can move and annotate card images.
- The cards in this activity are based on the NGSS and *A Framework for K-12 Science Education*. You may wish to adapt some of the cards or questions based on other standards. Note, however, that the focus of the activity is not on the NGSS or the *Framework* specifically. Rather, it is more about student thinking and how students are framing their learning.
- You may elect to use just one or two sets of cards (e.g., only the SEP cards, or the SEP and CCC cards) depending upon the activity. For example, if students are engaged in a graph interpretation activity, such as a [Data Point](#), you may ask them to identify the SEP and CCC cards that are most appropriate in helping them figure out the information presented.
- Potential connections to the NGSS are listed for many BioInteractive resources (in the “Curriculum Connections” section of each resource webpage). You may want to use the provided connections as a reference when using BioInteractive resources with students.
 - You can also search for BioInteractive resources connected to a specific NGSS standard. First, search for a resource on the [“Classroom Resources”](#) page. Then, proceed to the search results page, go the “Filter” section, and apply a “Curriculum Standards” filter.

PROCEDURE

There are many ways for both students and educators to use the cards. As a starting point, some suggestions are provided for the following (click links to go directly to each section):

- [Making Student Thinking Visible](#)
- [Formative Assessments](#)

Making Student Thinking Visible

You can have your students use the cards, either individually or in small groups, to identify which dimensions of science they engaged with during class. Have students engage with the cards within the context of a classroom activity, rather than having students focus on the content of the cards themselves.

For example, as students work through an activity on the evolution of Darwin's finches, such as the "[Effects of Natural Selection on Finch Beak Size](#)" Data Point, they may select the following cards as dimensions that they engaged with in their work:

- **SEP:** Analyzing and Interpreting Data (SEP4)
- **CCC:** Patterns (CCC1)
- **DCI:** Structure and Function (LS1.A), Independent Relationships in Ecosystems (LS2.A), Variation of Traits (LS3.B)

You may ask individual students or groups of students to share out the cards they selected and why, so that they can learn how other students thought through the activity.

Formative Assessments

Incorporating the cards during or after a classroom activity provides opportunities for formative assessments. As students engage in an activity, such as investigating a phenomenon, you can ask related questions to help drive their learning.

Below are questions related to each card set that you may ask students. You can choose which card set(s) to use and/or which questions to ask based on your classroom context. Click the following links to go directly to each section:

- [SEP Questions](#)
- [CCC Questions](#)
- [DCI Questions](#)

Questions for the SEP (Science and Engineering Practices) Cards

Asking Questions and Defining Problems (SEP1)

- What questions do you have about the phenomena you observed?
- What are some things we might need to figure out to explain this phenomenon/problem?
- Did you observe any patterns in this phenomenon that we should explore?

Developing and Using Models (SEP2)

- How could we represent the system we are trying to figure out?
- What are the different components and interactions we observed in the system?
- What science ideas can we figure out from this model so far? What do we still need?

Planning and Carrying Out Investigations (SEP3)

- What data do we need to figure out this phenomenon?
- What ideas do you have about how we could investigate this phenomenon further?
- Would we need to do more than one investigation to get the data we need?

Analyzing and Interpreting Data (SEP4)

- How could we make sense of the data provided?
- What do these data actually mean?
- What new questions emerge from these data?

Using Mathematics and Computational Thinking (SEP5)

- Why is making sense of the numbers here important to our understanding?
- Could we design a computational model to figure out processes we cannot see?

- What are other ways we could use mathematical or computational representations to figure out what is happening in the system?

Constructing Explanations and Designing Solutions (SEP6)

- Does your explanation use qualitative and/or quantitative data? Why?
- How are the variables/components of the system used to explain the phenomenon?
- What evidence most strongly supports your claim? Does any evidence refute your claim?
- What variable(s) did you identify as important when explaining the phenomenon?

Engaging in Argument from Evidence (SEP7)

- How can we distinguish evidence from other information?
- How does your evidence support or refute the claim?
- What are some misconceptions that your argument helps address?
- How does your argument compare to competing arguments?

Obtaining, Evaluating, and Communicating Information (SEP8)

- How do we know our sources are valid, reliable, and trustworthy?
- How can we best communicate this to others?
- How does hearing this information from others help us with our own work?

Questions for the CCC (Crosscutting Concepts) Cards

Patterns (CCC1)

- What patterns did you observe in the data?
- How did the patterns you observed help you figure out the phenomenon?
- How did the patterns you observed lead you to needing more information?

Cause and Effect (CCC2)

- What relationships exist that help you better understand the phenomenon?
- What were the causes and effects of the observed phenomenon?
- How did you know the relationship was causal and not just coincidence?

Scale, Proportion, and Quantity (CCC3)

- At what scale are you observing the phenomenon (cell, organism, population, etc.)?
- Can this phenomenon be studied directly, or must it be studied indirectly? Why?
- How could examining things at one scale help us to explain observations at another scale?

Systems and System Models (CCC4)

- How can we define this system? If it has “boundaries” or “conditions,” what are they?
- What are the major components of the system? Of the model?
- What are the limits of the model you are observing?

Energy and Matter (CCC5)

- How is energy and/or matter moving through the system you are observing?
- How is energy driving how matter moves within the system? Between systems?
- What are the [energy and/or matter] inputs and outputs in the system?

Structure and Function (CCC6)

- How does the structure of the _____ allow it to do its function?

- What would happen if the structure of _____ was changed?
- How does the structure and function of _____ affect the whole system?

Stability and Change (CCC7)

- How has the phenomenon changed or remained stable over time?
- How has this system maintained homeostasis? Or, what has made this system unable to maintain homeostasis?
- How does observing change in the short term help us better understand changes in the long term and vice versa?

Questions for the DCI (Disciplinary Core Ideas) Cards

The questions below are also shown on the DCI cards. These are overarching questions about the science content being investigated, which can help frame what students are trying to figure out. These questions originate in [A Framework for K-12 Science Education](#) and are also the main ideas found in the [Next Generation Science Standards](#) and most state science standards.

From Molecules to Organisms: Structures and Processes (LS1)

A. Structure and Function

- How do the structures of organisms enable life's functions?

B. Growth and Development of Organisms

- How do organisms grow and develop?

C. Organization for Matter and Flow in Organisms

- How do organisms obtain and use the matter and energy they need to live and grow?

D. Information Processing

- How do organisms detect, process, and use information about the environment?

Ecosystems: Interactions, Energy, and Dynamics (LS2)

A. Interdependent Relationships in Ecosystems

- How and why do organisms interact with their environment, and what are the effects of these interactions?

B. Cycles of Matter and Energy Transfer in Ecosystems

- How do matter and energy move through an ecosystem?

C. Ecosystem Dynamics, Functioning, and Resilience

- What happens to ecosystems when the environment changes?

D. Social Interactions and Group Behavior

- How do organisms interact in groups so as to benefit individuals?

Heredity: Inheritance and Variation of Traits (LS3)

A. Inheritance of Traits

- How are the characteristics of one generation related to those of the previous generation?

B. Variation of Traits

- Why do individuals of the same species vary in how they look, function, and behave?

Biological Evolution: Unity and Diversity (LS4)

A. Evidence of Common Ancestry and Diversity

- What evidence shows that different species are related?

B. Natural Selection

- How does genetic variation among organisms affect survival and reproduction?

C. Adaptation

- How does the environment influence populations of organisms over multiple generations?

D. Biodiversity and Humans

- What is biodiversity, how do humans affect it, and how does it affect humans?

REFERENCES

National Research Council. 2012. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/13165>.

NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press. <https://www.nextgenscience.org/>.

CREDITS

Written by Jason Crean, HHMI; Kristin Rademaker

Edited by Esther Shyu, Laura Bonetta, HHMI

Cards designed by Garré Tidey, HHMI