THINKING MAPS

Thinking Maps and the Next Generation Science Standards

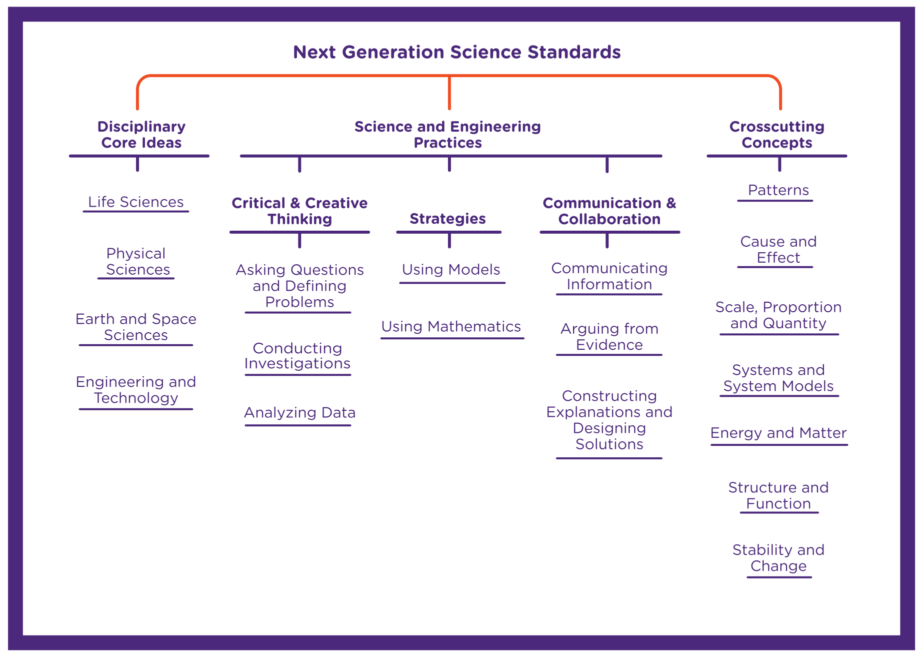
Supporting Disciplinary Core Ideas, Crosscutting Concepts, and Science and Engineering Practices

Thinking Maps is a shared visual "language for learning" that supports the development of critical thinking skills and the acquisition of content knowledge across all learning domains. They can be used in a variety of ways in the science classroom to help students understand and communicate complex scientific information, conduct experiments and inquiry-based activities, and learn to "think like a scientist." Thinking Maps aligns with the three dimensions of the Next-Generation Science Standards: Disciplinary Core Ideas, Crosscutting Concepts, and Science and Engineering Practices.

What Are the Next-Generation Science Standards (NGSS)?

The Next Generation Science Standards (NGSS) are a set of research-based K–12 science content standards that provide guidelines for what students should know and be able to do at each grade level in science. NGSS emphasizes three dimensions that are integrated into all standards:

- **Disciplinary Core Ideas (DCIs)**: These are the key ideas in science that have broad importance within or across multiple science disciplines, such as physical sciences, life sciences, Earth and space sciences, and engineering, technology, and applications of science.
- **Crosscutting Concepts (CCs)**: These concepts apply across all areas of science and include ideas such as patterns, cause and effect, and systems and system models.
- **Science and Engineering Practices (SEPs)**: These practices describe behaviors that scientists and engineers engage in as they investigate and build models and theories about the natural world or design and build engineering solutions.



Thinking Maps and the NGSS

Thinking Maps are research-based visual tools that support a deep understanding of, and engagement with, content and ideas. The eight visual patterns correspond to the eight fundamental cognitive processes that underlie learning in any domain: defining, describing, comparing/contrasting, classifying/categorizing, whole-to-part relationships, sequencing, cause and effect, and analogies. These basic modes of thinking are used across all the sciences and are foundational to understanding and applying scientific concepts, ideas and practices.

Thinking Maps provide a visual framework that helps students organize and process information, plan and implement experiments or activities, and communicate ideas effectively. They can be used to support all three dimensions of the NGSS.

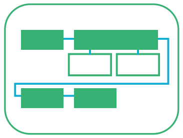
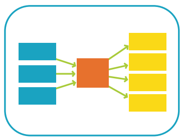
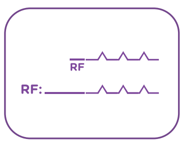
Disciplinary Core Ideas

The core ideas in the NGSS standards are organized into four main domains: Physical Sciences, Life Sciences, Earth and Space Sciences, and Engineering, Technology, and Applications of Science. Each domain consists of several Disciplinary Core Ideas (DCIs) that represent essential concepts students should understand by the end of their K-12 education. Thinking Maps help students master the DCIs and improve understanding, retention and recall of scientific information.

- **Organizing Knowledge**: Thinking Maps enable students to organize core ideas in a structured manner, making it easier to comprehend and retain complex scientific information. By visually linking related concepts, students can build a cohesive understanding of the subject matter.
- **Connecting Concepts**: Thinking Maps facilitate the connection of new knowledge to existing knowledge. By mapping out these connections, students can integrate new information with what they already know, deepening their overall understanding.
- **Communicating Understanding**: Thinking Maps provide a clear and organized way for students to present their understanding of core ideas. This visual communication can be especially useful in group discussions and presentations, where clarity and organization are key.

Thinking Maps can be used alone and in combination in a variety of ways to activate thinking processes and support information processing and comprehension. That makes the possibilities for their use in the science classroom virtually endless. The chart below represents just a few examples correlated to the DCIs.

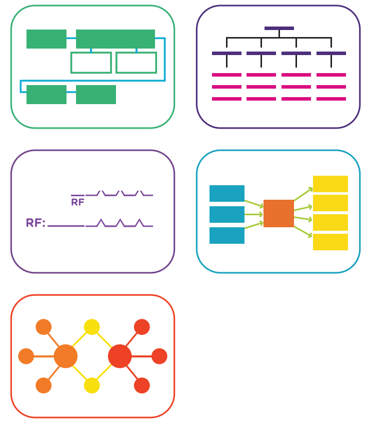
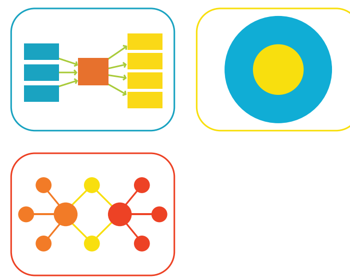
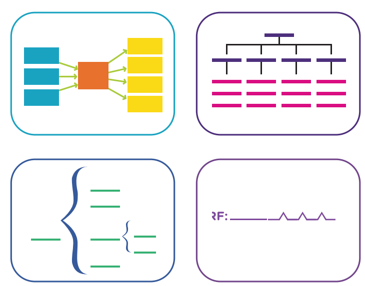
Thinking Map	Physical Sciences	Life Sciences	Earth and Space Sciences	Engineering, Technology and Applications
DEFINING IN CONTEXT CIRCLE MAP	Defining types of forces (PS2) Identifying sources of energy (PS3)	Defining an organism (LS1) Identifying roles within an ecosystem (LS2)	Defining weathering and erosion processes (ESS2) Identifying natural resources (ESS3)	Defining design constraints (ETS1) Identifying emerging technologies (ETS2)
DESCRIBING WITH ADJECTIVES BUBBLE MAP	Describing properties of different states of matter (PS1) Describing the attributes of an element (PS1)	Describing traits of an organism (LS1) Describing attributes of an ideal habitat for an organism (LS2)	Describing the attributes of a mineral (ESS2) Describing the attributes of the sun (ESS1)	Describing the attributes of design thinking (ETS1)
COMPARING/ CONTRASTING DOUBLE BUBBLE MAP	Comparing ionic vs. covalent bonds (PS1) Comparing potential and kinetic energy (PS3)	Comparing inherited and acquired traits (LS3) Comparing plant and animal cells (LS1)	Comparing igneous and sedimentary rocks (ESS2) Comparing Earth vs. Mars (ESS1)	Comparing two engineering solutions to the same problem (ETS1) Comparing the uses and attributes of two different technologies (ETS2)
CATEGORIZING AND CLASSIFYING TREE MAP	Classifying elements from the periodic table: metals, non-metals, metalloids, noble gasses, etc. (PS1) Classifying forms of energy: mechanical, thermal, chemical, electrical (PS3)	Classifying organisms: plants, animals, fungi, bacteria (LS1) Classifying components of an ecosystem: producers, consumers, decomposers (LS2)	Classifying elements of Earth's systems: geosphere, hydrosphere, atmosphere, biosphere (ESS2) Classifying types of natural resources: renewable and nonrenewable (ESS3)	Classifying engineering materials: metals, polymers, ceramics, composites (ETS1) Classifying impacts of technology on different aspects of society: economic, environmental, social (ETS2)
WHOLE TO PART BRACE MAP	Breaking down components of an atom: protons, neutrons, electrons (PS1) Breaking down parts of a circuit: power source, conductor, load (PS2)	Breaking down parts of the human digestive system: mouth, esophagus, stomach, intestines (LS1) Breaking down the parts of a cell (LS1)	Breaking down layers of the Earth: crust, mantle, core (ESS2) Breaking down parts of a hurricane: eye, eyewall, rainbands (ESS3)	Breaking down parts of a bridge: deck, supports, foundation (ETS1) Breaking down components of a computer network: endpoint devices, routers, modems, switches, servers (ETS2)

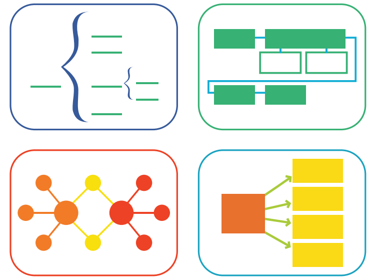
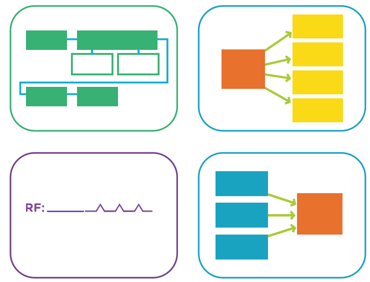
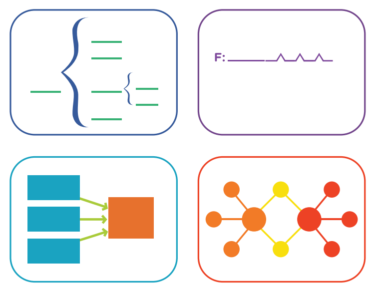
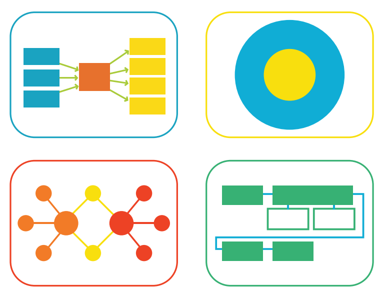
Thinking Map	Physical Sciences	Life Sciences	Earth and Space Sciences	Engineering, Technology and Applications
SEQUENCING  FLOW MAP	Sequencing steps of a chemical reaction (PS1) Sequencing steps in an energy transformation (PS3)	Sequencing stages of mitosis and meiosis (LS1) Sequencing energy flow in a food chain (LS2)	Sequencing stages of the water cycle (ESS2) Sequencing events in Earth's geological history (ESS1)	Sequencing steps in the engineering design process (ETS1) Sequencing stages of technology development (ETS2)
CAUSE AND EFFECT  MULTI-FLOW MAP	Analyzing causes and effects of force application (PS2) Analyzing the effects of radiation on different materials (PS4)	Analyzing causes and effects of genetic mutations (LS3) Analyzing the impact of invasive species on ecosystems (LS2)	Analyzing causes and effects of volcanic eruptions (ESS2) Analyzing effects of climate change on weather patterns (ESS3)	Analyzing the causes and effects of a failed engineering design (ETS1) Analyzing the effects of technological advancements on society (ETS2)
ANALOGIES AND RELATIONSHIPS  BRIDGE MAP	Relating types of energy to examples of motion (PS3) Relating chemical bonds to molecular structures (PS4)	Relating cell structure to function: nucleus to control center, mitochondria to energy production, etc. (LS1) Relating genotypes to phenotypes (traits) (LS3)	Relating phases of the moon to appearance on Earth (ESS1) Relating geologic processes (e.g., volcanos, erosion) to the landforms they create (ESS2)	Relating societal problems to engineering solutions (ETS1) Relating scientific discoveries to technological advances (ETS2)

Crosscutting Concepts

In the NGSS, Crosscutting Concepts are fundamental ideas that unify the various fields of science and enhance students' ability to understand and engage with scientific content in a meaningful way. These seven big ideas are essential for developing a well-rounded and integrated understanding of science. Thinking Maps are ideal tools for exploring the Crosscutting Concepts, making abstract ideas concrete and easy to understand.

Here are some examples of ways that Thinking Maps can support the Crosscutting Concepts.

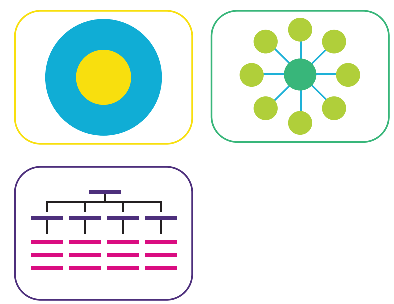
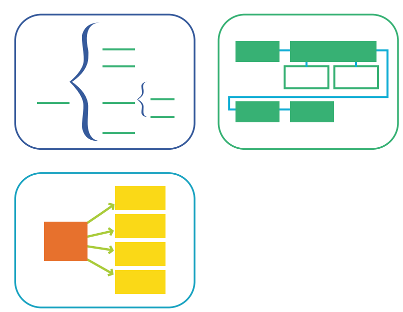
Crosscutting Concepts in Science	Critical Questions	Possible Thinking Maps	Standards-Based Connections
PATTERNS	• Is there a pattern? • What caused the pattern? • What predictions can I make? • How does this pattern compare to others?		• Flow Map or Bridge Map for analyzing patterns • Tree Map for classifying • Bridge Map for relationships • Multi-Flow Map for causes of patterns and making predictions • Double Bubble Map for comparing/contrasting (C/C) patterns
CAUSE AND EFFECT	• What evidence is there for this cause-and-effect (C/E) relationship? • How is this C/E relationship similar to others? • How does changing one event affect the results?		• Multi-Flow Maps for C/E • Circle Map for Brainstorming • Double Bubble Map for C/C
SCALE, PROPORTION AND QUANTITY	• How does this system look at a smaller or larger scale? • What is new, and what is the same? • How does this scale relate to you? • What happens if we change the quantity involved?		• Multi-Flow Map for C/E • Tree Map for details or examples at different scales • Brace Map for analyzing parts at different scales or proportions. • Bridge Map for relationships

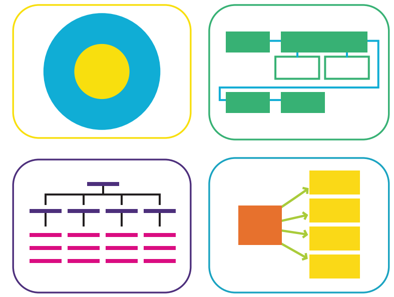
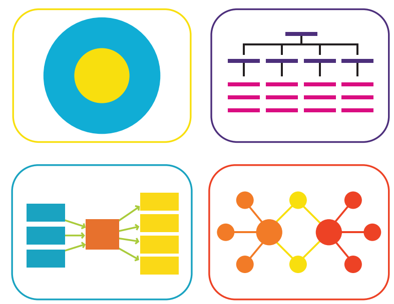
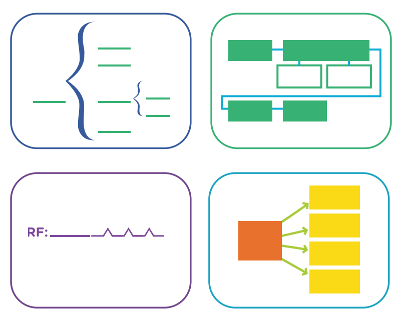
SYSTEMS AND SYSTEM MODELS	• What parts and sub-systems make up this system? • What interactions and processes involve this system? • How is this system alike or different from others? • What are the effects of modifying one part of the system?		• Brace Map for taking systems apart • Flow Map for organization of the system • Double Bubble Map to C/C systems • Partial Multi-Flow Map to analyze impact of modifying systems
ENERGY AND MATTER	• How are energy and matter related in this system? • Where does energy for this system come from? Where does it go?		• Flow Map for tracking energy • Partial Multi-Flow Map for effects and changes • Bridge Map for relating energy and matter • Partial Multi-Flow for causes of energy or matter transformations
STRUCTURE AND FUNCTION	• How does the function depend on structure? • Are there other structures that serve the same function?		• Brace Map to analyze structure • Bridge Map to show relationship of structure to function • Partial Multi-Flow Map to explain how structure causes the function • Double Bubble Map for C/C different structures
STABILITY AND CHANGE	• What causes change in this system? • Is the stability static or dynamic? • What are possible catalysts for changing the stability?		• Multi-Flow Map for C/E of change • Circle Map for defining dynamic and static stability • Double Bubble Map for C/C dynamic and static stability • Flow Map for evolution of a system

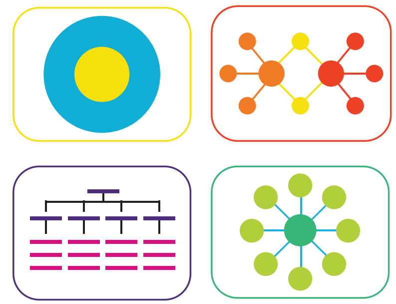
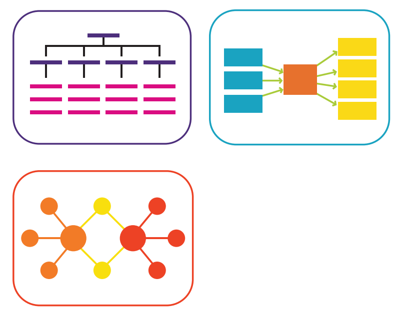
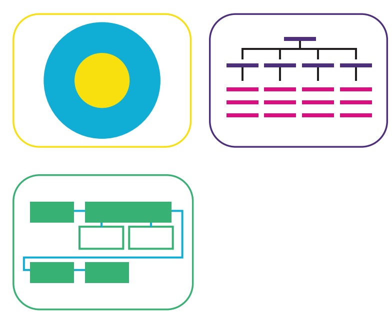
Science and Engineering Practices

Science and Engineering Practices (SEPs) are essential activities that scientists and engineers engage in as part of their work. These practices are integral to the NGSS and emphasize the skills and knowledge students need to understand and investigate the natural world and develop solutions to problems. SEPs help students understand that science and engineering are not just bodies of knowledge but also dynamic processes involving investigation, experimentation, and problem-solving. They emphasize the application of knowledge in real-world contexts and help students develop critical thinking, problem-solving, and analytical skills that are essential for scientific inquiry.

Thinking Maps support the SEPs by helping students develop and activate critical thinking skills and understand what type of thinking is required by a specific task. They also help students plan and implement inquiry-based activities. The chart shows a few examples of how Thinking Maps can be used to support each SEP.

Science and Engineering Practice	Critical Questions	Possible Thinking Maps	Standards-Based Connections
ASKING QUESTIONS AND DEFINING PROBLEMS	• What questions can we ask to understand this phenomenon better? • What are the main problems or challenges we need to solve? • How can we refine our questions to make them more specific and testable? • What background information do we need to formulate our questions or define our problem?		• Circle Map for gathering information or brainstorming questions • Bubble Map for describing problem characteristics or solution requirements • Tree Map for gathering information and identifying knowledge gaps
DEVELOPING AND USING MODELS	• What model can we create to represent this system or phenomenon? • How does our model help explain the relationships between different components? • What are the limitations of our model, and how can we improve it? • How can we use our model to predict outcomes or test hypotheses?		• Brace Map for breaking down a system into component parts • Flow Map for modeling the steps or stages in a process or cycle • Partial Multi-Flow Map for predicting outcomes

Science and Engineering Practice	Critical Questions	Possible Thinking Maps	Standards-Based Connections
PLANNING AND CARRYING OUT INVESTIGATIONS	• What is our hypothesis or research question for this investigation? • What materials and methods will we need to carry out our investigation? • How will we control variables and ensure our results are reliable? • What steps will we follow to conduct our investigation systematically?		• Circle Map for brainstorming questions and hypotheses • Flow Map for sequencing steps in the investigative process • Tree Map for determining materials needed and their uses • Partial Multi-Flow Map for predicting outcomes of the investigation or the impact of changing a step
ANALYZING AND INTERPRETING DATA	• What patterns or trends do we observe in the data? • How can we interpret the data to draw meaningful conclusions? • Are there any anomalies or unexpected results in the data? • How does the data support or refute our hypothesis?		• Circle Map or Tree Map for gathering data • Multi-Flow Map for analyzing results • Double Bubble Map for comparing predicted to actual results or comparing different data sets
USING MATHEMATICS AND COMPUTATIONAL THINKING	• What mathematical or computational tools can we use to analyze our data? • How can we represent our data using graphs, charts, or equations? • What calculations are necessary to understand the relationships in our data? • How can we use computational models to simulate and predict outcomes?		• Brace Map for breaking down mathematical equations into components • Flow Map for sequencing steps in a computational process • Brace Map for exploring mathematical relationships or proportions • Partial Multi-Flow Map for showing outcomes of a computational process

Science and Engineering Practice	Critical Questions	Possible Thinking Maps	Standards-Based Connections
CONSTRUCTING EXPLANATIONS AND DESIGNING SOLUTIONS	• What evidence do we have to support our explanation? • How does our explanation address the initial problem or question? • What criteria and constraints must our solution meet? • How can we design and test a solution to address the problem effectively?		• Circle Map for brainstorming possible solutions • Double Bubble Map for C/C possible solutions • Tree Map for gathering evidence in support of each solution • Bubble Map for describing solution requirements
ENGAGING IN ARGUMENT FROM EVIDENCE	• What evidence supports our argument, and how strong is it? • How can we present our evidence to make a compelling case? • What counterarguments exist, and how can we address them? • How do different pieces of evidence compare and contrast with each other?		• Tree Map for gathering and organizing evidence • Multi-Flow Map for explaining C/E relationships • Double Bubble Map for C/C our argument and possible counterarguments
OBTAINING, EVALUATING AND COMMUNICATING INFORMATION	• What sources of information are most reliable and why? • How can we evaluate the credibility of different sources? • What is the best way to communicate our findings to others? • How can we ensure our communication is clear, accurate, and engaging?		• Circle Map for gathering information • Tree Map for categorizing information from various sources • Flow Map for organizing a written product or oral presentation • Frame of Reference (in any Map) for evaluating sources of information, points of view and potential biases

Ready to learn more about using Thinking Maps in the science classroom?
Contact your Thinking Maps representative for more information.
www.thinkingmaps.com