Science

Module 11

High School Biology I – Life Science: Energy Flow

Module Goal

The goal of this module is to provide information that will help educators increase their knowledge of grade-appropriate science concepts, knowledge, and skills to support effective planning or modification of their existing science instructional units for students with significant cognitive disabilities. The module includes important concepts, knowledge, and skills for the following instruction:

- From Molecules to Organisms: Structures and Processes—Organisms capture, transform, release, and eliminate matter and energy to sustain them. The energy needed for life is ultimately derived from the sun through photosynthesis. Plants, algae (including phytoplankton), and other energy-fixing microorganisms use the process of photosynthesis to capture light energy from the sun and then transform it to chemical energy through the conversion of carbon dioxide and water into sugars. The plant releases oxygen into the atmosphere. Plants and algae—being the resource base for animals, animals that feed on other animals, and decomposers—are energy-fixing organisms that sustain the rest of the food web.
- Ecosystems: Interactions, Energy, and Dynamics—The cycling of matter and the flow of energy within ecosystems occur through interactions among different organisms and between organisms and the physical environment. Energy flows and cycling matter help meet the needs of organisms within the ecosystem. Photosynthesis and cellular respiration provide most of the energy for organisms and matter cycles between Earth's spheres (e.g., water cycle, nitrogen cycle) to sustain life in ecosystems. Photosynthesis, digestion of plant matter, respiration, and decomposition are important components of the carbon cycle, in which carbon is exchanged between the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. Matter also cycles through the food web; however, the amount decreases as it is transferred to higher levels of the food web. This results in fewer organisms at higher levels of a food web than at the lower levels. Ecosystems are dynamic in nature; their characteristics fluctuate over time, depending on changes in the environment and in the populations of various species. Ecosystems change over time and sometimes quickly in the case of a catastrophic event resulting in ecological succession. Changes may derive from the fall of canopy trees in a forest, for example, or from cataclysmic events, such as volcanic eruptions.

Module Objectives

The content module supports educators' planning and implementation of instructional units in science by:

- Developing an understanding of the concepts and vocabulary that interconnect with information in the module units.
- Learning instructional strategies that support teaching students the concepts, knowledge, and skills related to the module units.
- Discovering ways to transfer and generalize the content, knowledge, and skills to future school, community, and work environments.

The module provides an overview of the science concepts, content, and vocabulary related to Life Science: Energy Flow and provides suggested teaching strategies and ways to support transference and generalization of the concepts, knowledge, and skills. The module does not include lesson plans and is not a comprehensive instructional unit. Rather, the module provides information for educators to use when developing instructional units and lesson plans.

The module organizes the information using the following sections:

I. Tennessee Academic Standards for Science and Related Knowledge and Skills Statements and Underlying Concepts;
II. Scientific Inquiry and Engineering Design;
III. Crosscutting Concepts;
IV. Vocabulary and Background Knowledge information, including ideas to teach vocabulary;
V. Overview of Units' Content;
VI. Universal Design for Learning (UDL) Suggestions;
VII. Transference and Generalization of Concepts, Knowledge, and Skills; and
VIII. Tactile Maps and Graphics.

Section I

Tennessee Academic Standards for Science and Related Knowledge and Skills Statements and Underlying Concepts

It is important to know the expectations for each unit when planning for instruction. The first step in the planning process is to become familiar with the identified academic standards and the Knowledge and Skills Statements (KSSs) and Underlying Concepts (UCs) covered in the module. The KSSs are specific statements of knowledge and skills linked to the grade-specific science academic standards. The UCs are entry-level knowledge and skills that build toward a more complex understanding of the knowledge and skills represented in the KSSs and should not be taught in isolation. It is important to provide instruction on the KSSs along with the UCs to move toward acquisition of the same knowledge and skills.

Table 1 includes the academic standards and related KSSs and UCs for Life Science: Energy Flow. While only the academic standards targeted for the Tennessee Comprehensive Assessment Program/Alternate (TCAP/Alt) are included, instruction on additional standards will aid in student understanding. Standards that are not included still represent important content for students to master. Therefore, the KSSs and UCs included in the table do not cover all the concepts that can be taught to support progress and understanding aligned to the standards.

Table 1. Tennessee Academic Standards for Science and Related KSSs and UCs [1]

Academic Standard	Knowledge and Skill Statement (KSS)	Underlying Concept (UC) of the Academic Standard
From Molecules to Organisms: Structures and Processes (High school)		
BIO1.LS1.8: Create a model of photosynthesis demonstrating the net flow of matter and energy into a cell. Use the model to explain energy transfer from light energy into stored chemical energy in the product.	**BIO1.LS1.8.a:** Ability to identify that photosynthesis results in the conversion of light energy to stored chemical energy **BIO1.LS1.8.b:** Ability to identify components of a model which illustrates that photosynthesis transforms light energy into stored chemical energy (i.e., the conversion of carbon dioxide plus water into glucose plus released oxygen)	**BIO1.LS1.8.UC:** Recognize outcomes of photosynthesis (i.e., stores energy, forms plant matter, releases oxygen, and maintains plants' activities).

Ecosystems: Interactions, Energy, and Dynamics (High school)		
BIO1.LS2.2: Create a model tracking carbon atoms between inorganic and organic molecules in an ecosystem. Explain human impacts on climate based on this model.	**BIO1.LS2.2.a:** Ability to identify relevant components (i.e., inputs and outputs of photosynthesis; inputs and outputs of cellular respiration; biosphere, atmosphere, hydrosphere, and geosphere) of a model of the exchange of carbon between organisms and the environment **BIO1.LS2.2.b:** Ability to use a representation of Earth systems to identify the relationships among the Earth systems and how those relationships are being modified due to human activity	**BIO1.LS2.2.UC:** Identify how matter cycles through ecosystems (e.g., plants take in carbon dioxide from the atmosphere to build carbohydrates during photosynthesis; carbon moves through food chains as organisms eat other organisms).
BIO1.LS2.3: Analyze through research the cycling of matter in our biosphere and explain how biogeochemical cycles are critical for ecosystem function.	**BIO1.LS2.3.a:** Ability to use a model of the cycling of matter (e.g., water cycle, nitrogen cycle) to describe how it is needed to sustain life in ecosystems	**BIO1.LS2.3.UC:** Recognize that elements cycle between usable (glucose or NH_3) and unusable forms (carbon dioxide or N_2).
BIO1.LS2.4: Analyze data demonstrating the decrease in biomass observed in each successive trophic level. Construct an explanation considering the laws of conservation of energy and matter and represent this phenomenon in a mathematical model to describe the transfer of energy and matter between trophic levels.	**BIO1.LS2.4.a:** Ability to use a graphic representation to identify the changes in the amount of matter as it travels through each successive trophic level **BIO1.LS2.4.b:** Ability to use a graphical representation to identify the changes in the amount of energy as it travels through each successive trophic level	**BIO1.LS2.4.UC:** Recognize that there are generally fewer organisms at higher levels of a food web (e.g., a graphical representation) than at lower levels.
BIO1.LS2.5: Analyze examples of ecological succession, identifying and explaining the order of events responsible for the formation of a new ecosystem in response to extreme fluctuations in environmental conditions or catastrophic events.	**BIO1.LS2.5.a:** Ability to sequence events which occur during an example of ecological succession (i.e., abandoned gardens, ditch banks, volcanic eruption, and the edge of a forest) **BIO1.LS2.5.b:** Ability to recognize that how an ecosystem may change (i.e., plant communities change over time) following a catastrophic event (e.g., deforestation, flood, etc.) determines what kinds of animals may move into and out of the area	**BIO1.LS2.5.UC:** Recognize that natural disasters affect an ecosystem.

[1] Instruction is not intended to be limited to the concepts, knowledge, and skills represented by the KSSs and UCs listed in Table 1.

Section II

Scientific Inquiry and Engineering Design

It is important for students with significant cognitive disabilities to have the opportunity to explore the world around them and learn to problem solve during science instruction. This approach to science instruction does not involve rote memorization of facts; instead it involves scientific inquiry. A Framework for K-12 Science Education (2012) unpacks scientific inquiry, providing eight practices for learning science and engineering in grades K–12. These practices provide students an opportunity to learn science in a meaningful manner. Students should combine the science and engineering practices as appropriate to conduct scientific investigations instead of using a practice in isolation or sequentially moving through each practice. Support should be provided as necessary for students with significant cognitive disabilities to actively use the practices. A link to *Safety in the Elementary Science Classroom* is in the resources of this section. See Section VI. Universal Design for Learning Suggestions for support ideas. Following are the eight science and engineering practices (National Research Council, 2012) with added examples.

- Asking questions (for science) and defining problems (for engineering).
  Examples: How and why do organisms interact with each other (biotic factors) and their environment (abiotic factors), and what affects these interactions? What happens if a farmer uses too much fertilizer? Do large farms impact the local climate? What is the relationship between the nitrogen cycle and sustainability of organisms in an ecosystem? How do large livestock farms affect the nitrogen cycle? How is energy transferred from plants or animals on one level of an energy pyramid to animals on the next level? What happens to an ecosystem after a catastrophic event (e.g., forest fire, volcano eruption, hurricane)? How do matter and energy cycle through ecosystems? Consider how new technologies can have deep impacts on society and the environment, including some that were not anticipated.
- Developing and using models.
  Examples: Models (e.g., physical, mathematical, computer) can be used to simulate systems and interactions, including energy, matter, and information flows within and between systems at different scales. Create a model of the carbon cycle, refine it after researching other models of the carbon cycle, and then use it to discuss the role of natural and human carbon sinks and sources in modifying the carbon cycle. Create a model of an energy pyramid using plants and animals from a local ecosystem to generate predictions and explanations for energy flow in an ecosystem. Create and use a trophic pyramid of local flora and fauna to describe the relative numbers of organisms at the lower and higher levels of a food web within an ecosystem. Create a model of succession in an abandoned garden. Using food webs and ecological models, students can observe that the numbers and types of organisms are relatively constant over long periods of time under stable conditions.
- Planning and carrying out investigations.
  Examples: Conduct an investigation on the use of carbon dioxide by plants (e.g., https://serc.carleton.edu/sp/mnstep/activities/35653.html). Conduct an investigation on how photosynthesis and cellular respiration interact in a closed environment (e.g., http://www.cpalms.org/Public/PreviewResourceLesson/Preview/129054). Conduct an investigation on the use of glucose in cellular respiration. Select the appropriate tools to collect, record, analyze, and evaluate data during an investigation on the water cycle. Investigate the benefits and risks of capturing carbon dioxide and pumping deep underground into aquifers.

- Analyzing and interpreting data.
  Examples: Analyze data on the interrelatedness of photosynthesis and cellular respiration in a closed environment. Compare various data sets when examining climate change. Analyze and interpret data on converting nitrogen to a form that allows organisms to obtain nitrogen directly from the atmosphere (i.e., nitrogen fixation). Consider limitations of data analysis (e.g., sample selection) when analyzing data on an ecological succession. Analyze and interpret data on the amount of biomass observed in each successive trophic level. Interpret and use data regarding nitrogen fixation in a specific agricultural area to determine the effectiveness of newly instated farming techniques. Choose and interpret the scale and the origin in graphs and data displays that represent the cycling of matter and flow of energy among organisms in an ecosystem. Analyze data to make inferences and predictions about the impacts of future climate change and global warming on displacement or migration of humans.

- Using mathematics and computational thinking.
  Example: Use a mathematical model to describe the conservation of atoms and molecules as they move through an ecosystem. Measure the amount of water that enters a pipette to determine the amount of oxygen consumed through cellular respiration (see lab investigations in Science Practices Resources). Use a mathematical model to describe the cycling of matter and flow of energy among organisms in an ecosystem. Compute the amount of energy in each level of the energy pyramid of a given ecosystem. Calculate how much carbon plants store through photosynthesis. Use mathematical and/or computational representations (e.g., trends, averages, histograms, graphs, spreadsheets) of ecosystem factors to identify changes over time in the numbers and types of organisms in ecosystems.

- Constructing explanations (for science) and designing solutions (for engineering).
  Examples: Construct and revise an explanation based on evidence obtained from a variety of sources on the effect of human activity on Earth's systems. Make a claim regarding the relationship between photosynthesis and cellular respiration in a closed system. Use scientific reasoning, theories, and models to explain how cutting down 30 acres of woods to grow crops can affect the amount of carbon and nitrogen. Design a solution to maintain balance in a closed ecosystem (e.g., greenhouse). Develop and strengthen an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions by planning, revising, editing, rewriting, or trying a new approach.

- Engaging in argument from evidence.
  Examples: Use reasoning to connect evidence showing that energy inputs to cells occur either by photosynthesis or by taking in food. Students can construct arguments, using evidence, to support recognized patterns of change in factors such as global temperatures and their effect on populations and the environment. Support a claim using relevant data that there is a natural succession of plants and animals in an abandoned garden. Make a claim based on evidence about the effectiveness of a design to reduce the use of harmful pesticides in farming. Represent claims that complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions but changing conditions may result in a new ecosystem.

- Obtaining, evaluating, and communicating information.
  Examples: Communicate, using evidence, why there are fewer wolves or hawks in an ecosystem versus rabbits or robins. Gather information on the amount of energy as it travels through each successive trophic level. Evaluate competing design solutions for maintaining biodiversity in a forest. Evaluate reports of complex interactions and their effects on stability and change in ecosystems

based on data showing numbers and types of organisms in stable conditions and in changing conditions. Evaluate technological solutions that limit human impacts on natural systems.

Science Practices Resources[2]

- Safety in the Science Classroom provides safety information for teachers and students. http://static.nsta.org/pdfs/SafetyInTheScienceClassroom.pdf
- This site categorizes inquiry into three types: structured inquiry, guided inquiry, and open inquiry. http://www.justsciencenow.com/inquiry/
- Education.com provides a variety of life science activities and experiments. http://www.education.com/activity/life-science/

Section III

Crosscutting Concepts

Grade-level science content includes Crosscutting Concepts, which are concepts that connect information between different science strands and grade levels. The Crosscutting Concepts are intended to work together with the science inquiry and engineering practices, in addition to core content, to enable students to reason with evidence, make sense of phenomena, and design solutions to problems. Helping students make connections between these types of concepts and new content information supports comprehension of the concepts, knowledge, and skills as well as transference and generalization (see Section VII for more information). Crosscutting Concepts that are specific to this module connect to content across the units within the module as well as across modules.

Crosscutting Concepts are a common link between multiple standards and units of study. The Crosscutting Concepts, by being revisited and linked to multiple units of study, become a strong foundation of understanding and support the students in learning new concepts. Life sciences focus on patterns, processes, and relationships of living organisms. For example, understanding patterns of change is a Crosscutting Concept that applies to energy flows within an ecosystem, predictable transfer patterns, observations based on historical ecological data since energy moves through trophic levels, and patterns of interactions that occur between organisms and their environments, both living and nonliving. Some Crosscutting Concepts may apply across multiple content areas and instructional emphases (e.g., cause and effect in reading science texts). The Crosscutting Concepts of stability and change provide a framework for understanding how energy drives the cycling of matter (e.g., map the flow of energy and the simultaneous changes in matter in an ecosystem). This content module, Life Science: Energy Flow, addresses the process of photosynthesis and cellular respiration and how these processes result in matter and energy flow through organisms and Earth's systems. The module addresses cycling of matter (water cycle and nitrogen cycle), the cycling of energy through food webs, and formations of new ecosystems in response to extreme changes in an ecosystem.

Teaching Crosscutting Concepts

The following strategies pulled from the principles of UDL (CAST, 2011) are ways in which to teach Crosscutting Concepts to help students understand the concepts and make connections between different curricular content. During instruction, highlight:

- patterns (e.g., point out patterns in the shape of a graph or repeating patterns on a chart),
- critical features (e.g., provide explicit cues or prompts, such as highlighting, to help students attend to important features),
- big ideas (e.g., present and reinforce the "big ideas" that students should take and apply to the students' lives), and
- relationships (e.g., make the connection between the unit concepts and how they apply to the students' lives).

Following are **Crosscutting Concepts** for this Content Module—Life Science: Energy Flow. According to *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (2012), these concepts help provide students with an organizational framework for connecting knowledge from the various disciplines into a coherent and scientifically based view of the world.

Patterns

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of a phenomena (e.g., energy flow through photosynthesis and cellular respiration).

Causality

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects (e.g., how ecosystems respond to extreme fluctuations in environmental conditions or catastrophic events).

Systems

Systems and System Models

- A system can be described in terms of its components and their interactions (e.g., plants and animals). Models (e.g., physical, mathematical, computer) can be used to simulate systems and interactions—including energy, matter and information flows—within and between systems at different scales (e.g., models of regional ecosystems and global ecosystem types).

Energy and Matter

- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system (e.g., photosynthesis).
- Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems (e.g., energy and matter cycling through organisms in a food web).
- Energy drives the cycling of matter within and between systems (e.g., water cycle, nitrogen cycle).

Stability and Change

- Much of science deals with constructing explanations of how things change and how they remain stable (e.g., human impact on the environment and biodiversity, ecological succession).
- Models (e.g., physical, mathematical, computer) can be used to simulate systems and interactions—including energy, matter and information flows—within and between systems at different scales (e.g., cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere at different scales).

Crosscutting Concept Resources

- Grant Wiggins talks about "big ideas" in this article.
http://www.authenticeducation.org/ae_bigideas/article.lasso?artid=99

- A Framework for K-12 Science Education, Appendix G explains the crosscutting concepts and how the concepts help students deepen their understanding of the information.
http://www.nextgenscience.org/sites/default/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf

- Teacher Vision provides ten science graphic organizers that are free and printable. https://www.teachervision.com/graphic-organizers/science/52539.html
- Utah Education Network provides a variety of student interactives for:
    - grades three through six. http://www.uen.org/3-6interactives/science.shtml
    - grades seven through twelve. http://www.uen.org/7-12interactives/science.shtml

Section IV

Vocabulary and Background Knowledge

Vocabulary is critical to building an understanding of science concepts, knowledge, and skills. The vocabulary words that students gain through experiences provide ways for students to comprehend new information (Sprenger, 2013). Students can better understand new vocabulary when they have some background knowledge to which they can make connections. In addition, learning new vocabulary increases students' background knowledge. Therefore, it is important to teach vocabulary purposely when introducing new concepts, knowledge, or skills (e.g., energy and matter at trophic levels) and in the context of the specific content (e.g., Teach the terms "consumer" and "producer" while students complete energy pyramids.).

This module includes two types of vocabulary words, both equally important to teach. The first type, **general vocabulary words,** labels groups of words that generalize to a variety of animals, plants, organisms, and activities. For example, understanding the meaning of the word "carbon" helps students understand photosynthesis and cellular respiration. The second type, **specific content words,** represents groups of words that are associated with an organism, system, process, or phenomena. For example, the specific term "nitrogen cycle" connects to the general words "atmosphere," "geosphere," "hydrosphere," and "biosphere" when learning how nitrogen cycles through Earth's spheres. Providing exposure and instruction on general words provides background knowledge when introducing corresponding or related specific words.

Key Vocabulary for Instructional Units

Table 2 and Table 3 contain lists of key general vocabulary words and specific content words that are important to the units in this module. Teach general vocabulary words to the student using a student-friendly description of the word meaning (e.g., Species is a distinct group of plants or animals that share characteristics.) and an example of the word (e.g., Wolves are an example of animal species.). Teach the specific content vocabulary using a student-friendly description of the word meaning (e.g., Pioneer species are the first plants to grow in an ecosystem following a disturbance.) and a possible connection to a general vocabulary word (e.g., The first plants to grow in an ecosystem after a volcano erupts and disturbs it are called a pioneer species.).

Do not teach memorization of vocabulary words; instead, place emphasis on understanding the word as a result of observation, investigation, viewing a model, etc. For example, a student should be able to identify that there is less energy at the top of an energy pyramid instead of defining the term.

Table 2. General Vocabulary Words

General Vocabulary—words that generalize to different animals, plants, organisms, and activities. Describe the word and provide examples (e.g., Carbon dioxide is a gas that animals breathe out and plants take in. *Example: Plants use carbon dioxide and water to make glucose.).*		
• atmosphere	• deforestation	• hydrosphere
• biomass	• earthquake	• matter
• biosphere	• ecology	• oxygen
• carbon	• ecosystem	• population
• carbon dioxide	• energy	• producer
• chemical energy	• environment	• solar/light energy
• chemical reaction	• flood	• species
• climate	• geosphere	• stored energy
• community	• glucose	• tornado
• consumer	• habitat	• transform
• decomposer	• hurricane	• volcano

Table 3. Specific Content Words

Specific Content Words—words that specify a particular thing (e.g., sedimentary rock) or phenomena (e.g., biodiversity). Describe the word and when possible make the connection to a Crosscutting Concept (e.g., Carbon sinks are natural systems that store carbon dioxide from the atmosphere. A system (e.g., ecosystem) can be described in terms of its components (carbon sinks such as plants, oceans, soil) and their interactions (e.g. cycling between the biosphere, geosphere, and atmosphere).		
• abiotic factor	• ecological succession	• pioneer species
• biotic factor	• energy flow	• primary succession
• carbon cycle	• energy pyramid	• secondary species
• carbon sink	• energy transfer	• secondary succession
• carbon source	• food chain	• succession
• cellular respiration	• food web	• trophic level
• climax forest/community	• nitrogen cycle	• water cycle
• deforestation	• photosynthesis	

Ideas to Support Vocabulary Learning

Table 4 includes ideas and examples for teaching vocabulary in ways to build conceptual understanding of the words. The examples include ideas on how to provide individualization, indicated in brackets, for unique student needs. These individualization ideas are provided to guide educators in ways to create access to vocabulary instruction for individual students.

Table 4. Ideas to Teach Vocabulary Effectively (Marzano, 2004)[1]

Ideas	Examples
Explain, describe, and/or give examples of the vocabulary word rather than formal definitions.	• Provide a description and an example of a producer, "An organism that makes its own food through photosynthesis."
Have students restate the vocabulary word in their own words. Take this opportunity to help students connect new vocabulary, especially general vocabulary, to prior knowledge.	• Have students name a familiar animal or plant and tell whether it is a producer, primary consumer, or secondary consumer. [Individualization idea: Have students describe the vocabulary word verbally or using an alternative and augmentative communication [AAC] system.]
Have students represent vocabulary words in a variety of ways (e.g., pictures, symbols, graphic organizers, or models).	• Have students complete a vocabulary graphic organizer that includes the targeted word, definition, an example, sentence, and related terms (see Figure 1. Example Vocabulary Graphic Organizer). [Individualization idea: Provide students with preprinted definitions, examples, sentences, and related terms to choose from to complete the organizer]. • Have students view words paired with pictures and recorded definitions. For example: ○ water cycle (e.g., https://quizlet.com/232101984/water-cycle-flash-cards/), ○ carbon cycle (e.g., https://quizlet.com/278584306/carbon-cycle-flash-cards/), and ○ nitrogen cycle (e.g., https://quizlet.com/285100774/nitrogen-cycle-flash-cards/).
Provide multiple exposure to vocabulary words in a variety of ways. This does not suggest mass trials, but rather distributed trials in different ways or contexts. Reference http://projectlearnet.org/tutorials/learning_trials.html for information on learning trials.	• Use vocabulary around the classroom and school (e.g., When watering plants, point out that plants are producers and how photosynthesis provides the oxygen we need to breathe.). • Read books or watch videos related to vocabulary and concepts: ○ consumers and producers (e.g., http://bookbuilder.cast.org/view.php?op=view&book=89265&page=1) and

Ideas	Examples
	○ food chains and webs (e.g., http://bookbuilder.cast.org/view.php?op=view&book=7077&page=1). • Have students create a word cloud (e.g., https://tagul.com/create).
Ask students to discuss the vocabulary words with each other.	• Have students share a definition or description of a word and have others guess the word. • Have students share their representations (e.g., drawings or pictures) of a word with each other.
Play vocabulary word games with students.	• Have students work with an interactive word wall (e.g.,http://nstacommunities.org/blog/2013/10/16/putting-science-words-on-the-wall/). • Play an online vocabulary game (e.g., https://www.texasgateway.org/resource/ecological-succession).
Have students watch a dramatization or have them act out the vocabulary term.	• Have students use charades, possibly with props, to describe vocabulary terms (e.g., use picture cards to dramatize the water cycle).

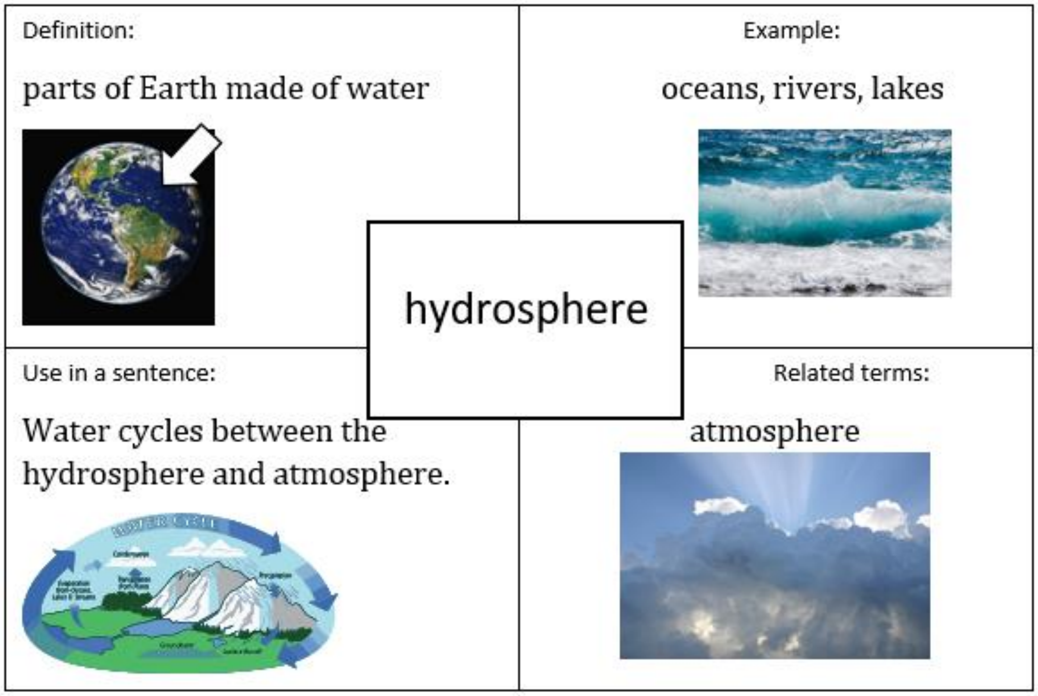
[1] Refer to Section VI, Universal Design for Learning (UDL) Suggestions for additional instructional strategies.

Vocabulary Example

Have students complete a vocabulary graphic organizer that includes the targeted word, definition, an example, sentence, and related terms. [Individualization ideas: Provide students with preprinted definitions, examples, sentences, and related terms to choose from to complete the organizer. Pair words and sentences with pictures. Create the graphic organizer in a slide show and have students complete using an adapted keyboard.] Two National Center and State Collaborative (NCSC) resources are available and may prove helpful:

- Use systematic instruction as described in the NCSC Instructional Guide. https://wiki.ncscpartners.org
- Reference ideas in the NCSC Vocabulary and Acquisition Content Module. https://wiki.ncscpartners.org

Figure 1. Example Vocabulary Graphic Organizer



Vocabulary Resources

- Vocabulary.com provides explanations of words using real-world examples. Once signed in, an educator can create word lists for students. http://www.vocabulary.com/
- TextProject provides Word Pictures that are free for educators to use. Their site includes word pictures for core vocabulary and various content areas including science and social studies. This link will take you to the Word Pictures page where you can select the category of words you want to use. http://textproject.org/classroom-materials/textproject-word-pictures/
- The Science Penguin site provides ideas to teach science vocabulary. The vocabulary demonstration activity uses real objects to teach vocabulary terms. http://thesciencepenguin.com/2013/12/science-solutions-vocabulary.html

Section V

Overview of Units' Content

This section of the module contains additional content and references to support educators' understanding and instruction of the instructional units. The information reflects important content to address the KSSs and to build students' knowledge, skills, and abilities; however, it is not exhaustive and should be expanded upon as appropriate.

From Molecules to Organisms: Structures and Processes

Content

- Photosynthesis is the process plants use to make their food and store energy.
- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.
- Photosynthesis transforms light energy into stored chemical energy.
  - Plants, algae, and some bacteria receive energy in the form of light.
  - Light energy is used to make glucose from water and carbon dioxide plus released oxygen.
- A model can illustrate how photosynthesis transforms energy into stored chemical energy. Examples:
  - graphic (e.g., http://www.phschool.com/science/biology_place/biocoach/photosynth/overview.html),
  - equation

    $$6H_2O + 6CO_2 + \text{sunlight} \rightarrow C_6H_{12}O_6 + 6O_2$$

    (water + carbon dioxide + sunlight → glucose + oxygen)
  - diagram (e.g., http://lifeofplant.blogspot.com/2011/04/energy-flow-in-plant-cells.html).

Ecosystems: Interactions, Energy, and Dynamics

Content

Carbon Cycle

- Carbon cycles between Earth's biosphere, geosphere, hydrosphere, and atmosphere (e.g., Carbon dioxide is in the atmosphere. → Plants use the carbon dioxide from the atmosphere and store carbon. → When plants die, they eventually turn into fossil fuels made of carbon. → Humans burn fossil fuels, which emit carbon into the atmosphere as carbon dioxide).
- Photosynthesis and cellular respiration are important components of the carbon cycle.
  - Plants, through photosynthesis, take in carbon dioxide and sunlight and output oxygen and glucose.
  - People and animals, through cellular respiration, use oxygen and glucose for energy and output carbon dioxide.
- Human interactions modify these cycles, causing problems with the ecosystem. They impact the balance of carbon sinks and carbon sources (e.g., Deforestation reduces the sink and allows more carbon dioxide to remain in the atmosphere. Human use of fossil fuels releases more carbon in the atmosphere than naturally occurs.).

- Plants, soil, oceans, and fossil fuels absorb and store carbon dioxide from the atmosphere (carbon sinks).
- Dying plants, naturally occurring forest fires, and volcanoes release carbon dioxide into the atmosphere (carbon sources).

- An unnatural increase in carbon dioxide in the atmosphere impacts the climate.
- Human activities cause pollution, which is transported in the water cycle (e.g., Water runoff carries fertilizer, animal waste, and pesticides into rivers, lakes, and oceans.).
- Human activities such as deforestation, burning of fossil fuels, etc., impact the climate.

Cycling of Matter

- Water cycles between Earth's spheres through evaporation, condensation, and precipitation.
- Nitrogen cycles between the biosphere, geosphere, and atmosphere on Earth (e.g., Nitrogen is deposited from the atmosphere into soil and surface waters through precipitation. → Bacteria converts nitrogen into ammonium, which is absorbed by plants. → Animals obtain nitrogen in the form of amino acids, nucleic acids, and chlorophyll from eating plants. → Plants and animals die and decay in the ground. → Decomposers turn the nitrogen from the decaying plants and animals back into ammonium. → Extra nitrogen in the soil is released into the atmosphere.
- Humans add nitrogen into the soil with fertilizer, which adds more nitrogen than is needed by the normal cycle.
- Models are used to describe the cycling of matter (e.g., water cycle, nitrogen cycle) and how humans can impact these cycles.

Transfer of Matter and Energy between Trophic Levels

- Energy flows through solar (light) energy → producers → primary consumers (herbivores) → secondary consumers (predators/carnivores) → tertiary consumers (top of the food chain predators).
- Trophic levels represent the movement of energy and matter in a food chain:
  - first level – producer – make its own food (e.g., plant)
  - second level – primary consumer – consumes producers (e.g., mice)
  - third level – secondary consumer – consumes primary consumers (e.g., snakes)
  - fourth level – tertiary consumer – consumes secondary consumers (e.g., hawks)
- The amount of biomass usually decreases at each successive trophic level (i.e., more at producer level and less at the tertiary consumer level).
- Only a fraction of matter consumed at the lower level of a food web is transferred up, resulting in fewer organisms at higher levels.
- The amount of energy decreases at each successive trophic level (i.e., more at producer level and less at the tertiary consumer level).
- On average, regardless of scale, approximately 10% of energy is transferred up from one trophic level to another.
- Matter and energy flow in trophic levels can be represented graphically (e.g., energy pyramid, food chains, food webs, and biomass pyramids).

Ecological Succession

- Ecological communities form and change over time.
- A series of progressive changes in the species that make up a community over time is referred to as ecological succession.
- Human disturbances to the environment (e.g., farming, logging) and natural disturbances (e.g., hurricanes, tornadoes, volcanic eruptions) can cause a succession.
- Primary succession occurs when an event such as a volcanic eruption leaves only bare rock.
- Secondary succession occurs when a disturbance happens that destroys plants and causes animals to leave, but the soil remains (e.g., forest fire, logging).
- When an ecological community or much of the community has been disturbed, a sequence of events occurs. Examples:
    - lichens → mosses → grasses and weeds → herbaceous plants → shrubs → young forest (tulip poplar) → mature forest (pines, hickories, immature oaks) → climax forest (oaks, hickories, black walnuts, maples, tulip poplars, beeches).
- When an ecosystem changes, either over time (e.g., plant communities change) or a catastrophic event (e.g., deforestation, flood, etc.), it affects what kind of animals may move into and out of the area.

Unit Content Resources

Photosynthesis

- This site has information on photosynthesis and cellular respiration. https://www.rtmsd.org/Page/11268
- Lumen Learning has information and key points on photosynthesis. https://courses.lumenlearning.com/boundless-biology/chapter/overview-of-photosynthesis/
- This site provides information and videos on photosynthesis. https://allinonehighschool.com/photosynthesis/
- NGSS Biology has multiple lesson plans on photosynthesis and cellular respiration. https://www.ngsslifescience.com/science.php/science/biology_lesson_plans_bioenergetics
- This site has a lesson plan on photosynthesis. https://www.acs.org/content/dam/AACT/middle-school/reactions/photosynthesis/secure/Lesson_Photosynthesis.doc
- This site has information and a graphic about energy cycle in living things. http://hyperphysics.phy-astr.gsu.edu/hbase/Biology/enercyc.html
- This site details how to construct a 3-D model representing glucose molecule photosynthesis. http://www.perkinselearning.org/accessible-science/building-organic-molecule
- This site has a lesson plan on cellular respiration and photosynthesis. http://www.cpalms.org/Public/PreviewResourceLesson/Preview/129054

Water, Carbon, and Nitrogen Cycles

- This site has a lesson plan and diagram on carbon sinks and sources. https://www.tigurl.org/images/tiged/docs/activities/565.pdf
- Lumen Learning has information on nutrient cycles (e.g., sources and sinks of essential elements, carbon cycle, and nitrogen cycle). https://courses.lumenlearning.com/boundless-microbiology/chapter/nutrient-cycles/

- cK-12 has information on the carbon cycle and the nitrogen cycle. https://www.ck12.org/book/CK-12-Earth-Science-For-High-School/section/18.2/
- This site includes a diagram and basic description of the:
  - carbon cycle https://eo.ucar.edu/kids/green/cycles6.htm and
  - nitrogen cycle. https://eo.ucar.edu/kids/green/cycles7.htm
- Ducksters has information on the nitrogen cycle. https://www.ducksters.com/science/ecosystems/nitrogen_cycle.php

Human Impact on Climate and Ecosystems

- This site has information on human activities and climate change. https://www.science.org.au/learning/general-audience/science-booklets-0/science-climate-change/3-are-human-activities-causing
- CLEAN provides information and links to lesson plans regarding human activities impacting the climate system. https://cleanet.org/clean/literacy/principle_6.html
- NASA has a lesson on climate change. https://climate.nasa.gov/resources/education/pbs_modules/lesson1Overview/
- NASA Wavelength has multiple lessons on the carbon cycle and climate change. http://nasawavelength.org/list/1142
- This site has a lesson plan on climate change. https://www.chicagobotanic.org/nasa/Grades_10-12_Unit_1

Matter and Energy at Trophic Levels

- National Geographic provides information on food webs. http://nationalgeographic.org/encyclopedia/food-web/
- Sciencing describes trophic levels in the ecosystem. https://sciencing.com/trophic-levels-ecosystem-8205653.html
- These sites have examples of energy pyramids:
  - https://www.learner.org/courses/essential/life/session7/closer5.html and
  - https://temperategrasslandegrossman.weebly.com/energy-pyramid.html.
- cK-12 has information and diagrams about trophic levels, energy, and biomass. https://www.ck12.org/biology/trophic-level/lesson/Trophic-Levels-BIO/
- CPALMS has a lesson plan on food webs and energy transfer. http://www.cpalms.org/Public/PreviewResourceLesson/Preview/29207
- This site has information on graphic representations of energy and matter at trophic levels. https://biology.tutorvista.com/ecology/ecological-pyramid.html
- This site has a lesson plan on building an energy pyramid. https://www.mtsu.edu/glade-center/teaching/19_Energy%20Pyramid.pdf
- Annenberg Learner has an online textbook with information on energy flow through the ecosystems. https://www.learner.org/courses/envsci/unit/text.php?unit=4&secNum=3
- Shmoop provides information on energy flow including an energy flow pyramid and a food web. http://www.shmoop.com/ecology/ecosystem-energy-flow.html

- This site presents a video on an energy pyramid and explains how the amount of energy decreases at each higher level of the pyramid. https://www.youtube.com/watch?v=CReZd9OHEfs
- Serendip provides an activity-based lesson plan on energy flow. http://serendip.brynmawr.edu/exchange/bioactivities/foodweb

Ecological Succession

- Khan Academy has information on ecological succession. https://www.khanacademy.org/science/biology/ecology/community-structure-and-diversity/a/ecological-succession
- Encyclopedia Britannica has information and a diagram on ecological succession. https://www.britannica.com/science/ecological-succession
- These sites have slide shows on ecological succession:
  - https://fl01000126.schoolwires.net/site/handlers/filedownload.ashx?moduleinstanceid=3708&dataid=6119&FileName=Ecological%20Succession%20PPT.ppt and
  - http://www.mtgilead.k12.oh.us/userfiles/1062/Classes/7797/Ecological%20Succession%20Ch2%20Section2.ppt
- Texas Gateway has a lesson plan, videos, and interactives about ecological succession. https://www.texasgateway.org/resource/ecological-succession
- This site has a summary on ecological succession. http://www.countrysideinfo.co.uk/successn/summary.htm

Section VI

Universal Design for Learning (UDL) Suggestions

Three principles of the UDL—multiple means of representation, multiple means of action and expression, and multiple means of engagement—guide development of instruction, instructional materials, and assessments to provide access to learning to the widest range of students. A well-designed lesson using the principles of UDL reduces the need to make accommodations and modifications. However, some students with significant cognitive disabilities, especially students with visual and/or hearing impairments, physical disabilities, and students with complex communication needs, may require additional scaffolds, adaptations, and modifications to access content and support learning. UDL's three guiding principles guide educators in creating instructional materials and activities in a flexible manner to address the needs of different types of learners. Utilizing the three principles of UDL as a framework when designing instruction allows for individualization when needed. Table 5 provides strategies and examples for the UDL Principle I, **Multiple Means of Representation**: presenting information in a variety of ways to address the needs of different types of learners. Table 6 provides strategies and examples for the UDL Principle II, **Multiple Means of Action and Expression**: providing a variety of ways for students to interact with the instructional materials and to demonstrate understanding. Table 7 provides strategies and examples for the UDL Principle III, **Multiple Means of Engagement**: providing a variety of ways to engage and motivate students to learn.

The strategies and examples provided in Tables 5 through 7 are based on UDL principles and can assist all students in understanding the basic concepts. The strategies and examples, as well as individualization ideas, should serve as a catalyst for ideas that can be individualized to meet the needs of each student. Some of the examples include activities that work exceptionally well for students with vision, hearing, and/or physical limitations as well as for all students. Each example has a code to indicate when it includes specific ideas or activities that meet these needs:

V = visually impaired (low vision, blind, or deaf-blind)
H = hearing impaired (deaf, hard of hearing, or deaf-blind)
P = physical disability (limited use of hands)

Table 5. Instructional strategy ideas using the UDL Principle: Multiple Means of Representation

Multiple Means of Representation	
Strategies	**Examples**
Introduce information through a multi-sensory approach (e.g., auditory, visual, tactile).	Have students explore three-dimensional or tactile models of: • photosynthesis (e.g., https://www.keslerscience.com/teach-photosynthesis-with-a-3d-tree-leaf-model-freebie/), • water cycle (e.g., https://www.earthlearningidea.com/PDF/168_Water_2.pdf) and • carbon cycle (e.g., https://eo.ucar.edu/kids/green/cycles6.htm). **V** Conduct a class investigation on the water cycle (e.g., https://www.adabofgluewilldo.com/water-cycle-bottle-science-experiment/). Share animations or videos on ecological succession (e.g., https://www.youtube.com/watch?v=E0qdWoLdk1c or https://www.youtube.com/watch?v=k03vxRYsJ4Y). [Individualization idea: Read and sign the text on the animations and videos. **H]**
Model content through pictures, dramatization, videos, etc.	Conduct a kinesthetic activity on cellular respiration (e.g., http://www.perkinselearning.org/accessible-science/cellular-respiration-kinesthetic-activity). [Individualization idea: Provide students with signs that have the terms and representative pictures of the terms to use to answer the questions.] Share videos on: • photosynthesis and cellular respiration (e.g., https://www.youtube.com/watch?v=JEnjph9miK4) • carbon and nitrogen cycles (e.g., https://www.youtube.com/watch?v=NHqEthRCqQ4). [Individualization idea: Help students move a symbol for carbon and nitrogen around a model of the cycles as they watch the video.]
Present information using graphic organizers and models.	Use a KWHL to help students make connections between what they already **K**now, **W**hat they want to know, **H**ow they can find out, and finally, what they **L**earn. (Here's a slide show explaining the use of the KWHL chart and how it was made accessible for students with significant cognitive disabilities: https://nceo.umn.edu/docs/Teleconferences/tele14/CourtadeFlowers.pdf). **V/H/P** Use an extended version of the KWHL: What do I **K**now? What do I **W**ant to know about or wonder about (e.g., a phenomena)? **H**ow will I find out (e.g., determine how to organize investigations)? What have I **L**earned? What **A**ction will I take (e.g., share with others, apply to daily life, etc.)? What new **Q**uestions do I have? More information can be found at http://langwitches.org/blog/2015/06/12/an-update-to-the-upgraded-kwl-for-the-21st-century/. [Individualization idea: Use strategies for the KWHL chart for accessibility ideas: https://nceo.umn.edu/docs/Teleconferences/tele14/CourtadeFlowers.pdf.]

Multiple Means of Representation	
Strategies	**Examples**
	Present an energy pyramid of a local ecosystem with pictures representing the organisms in each level (e.g., https://www.learner.org/courses/essential/life/session7/closer5.html) when explaining the decrease in the amount of useful energy at the higher trophic levels. [Individualization idea: Create the energy pyramid with removable plants and animals and have students place them in the correct level on the energy pyramid. Place each plant and animal on a small block to ease manipulation. **P**]
Provide appropriate and accessible text on the content for students to listen to or read.	Provide articles related to the unit topics. [Individualization ideas: Increase accessibility of the text by shortening it to reduce text difficulty and length (e.g., http://textcompactor.com/), augment the text (e.g., pictures, repeated key idea, partner reading, etc.), and write or type with a bold and plain font (e.g., Verdana, 18 pt. font) with good spacing between lines (e.g., 1.5 vs. single spacing).] **V** Provide digital texts with built-in text to speech software (e.g., photosynthesis and cellular respiration, http://bookbuilder.cast.org/view.php?op=view&book=109552&page=1).
Teach information using songs, poems, or rhymes.	Teach about the food chain and transfer of energy through a song (e.g., https://www.youtube.com/watch?v=TE6wqG4nb3M) or the carbon cycle (e.g., https://www.youtube.com/watch?v=bWaEB4BMFAQ).

Table 6. Instructional strategy ideas using the UDL Principle: Multiple Means of Action and Expression

Multiple Means of Action and Expression	
Strategies	**Examples**
Use technology/assistive technology to optimize student access and interaction with the instructional materials and content.	Have students enter data into a spreadsheet (e.g. carbon emissions or climate data). [Individualization ideas: Increase accessibility as needed. For example, use size 18 pt. or higher font, set up to allow use by a screen reader. Provide a task analysis for entering data and inserting a chart.] **V** Have students play online games: • photosynthesis and respiration (e.g., https://biomanbio.com/HTML5GamesandLabs/PhotoRespgames/photoresphtml5page.html) and • ecological succession (e.g., https://biomanbio.com/HTML5GamesandLabs/EcoGames/succession_interactive.html).
Allow for instructional materials that can be modified to provide access.	Place printed text and pictures on a slant board. **V/P** Have students read online texts related to unit topics (e.g., carbon cycle and climate https://www.ck12.org/c/earth-science/carbon-cycle-and-climate/lesson/Carbon-Cycle-and-Climate-HS-ES/). [Individualization idea: Increase the font size by clicking ctrl +. **V** Have students use a text to speech software.] Provide a paper stabilizer (e.g., removable tape or glue, nonslip mat, clipboard, etc.) to prevent paper from moving when the student is drawing, writing, reading, or pasting. **P**
Provide multiple means for students to make choices and select answers.	Have student dictate answers. [Individualization idea: Place answer options in the student's AAC device or on multi-select voice output switch.] **P** Provide answer choices. [Individualization idea: Have students use three switches with generic labels (e.g., a, b, c; red, blue, green; or three different textures) to which they listen, and then choose their answer.] **V/P** Allow multiple ways to indicate an answer when working with paper materials. [Individualization idea: Allow student to select answer using touch, large pencil grip, paper stabilizer, eye gaze board, etc.] **P** Have students answer yes/no questions. [Individualization idea: Place yes and no symbols on a voice output switch for students to use to answer yes/no questions. **P**]
Provide simulation activities.	Have students participate in activities that simulate photosynthesis and cellular respiration (e.g., https://www.calacademy.org/educators/lesson-plans/modelling-photosynthesis-and-cellular-respiration). [Individualization ideas: Create steps, directions, or a checklist and pair each with pictures. Have students work as partners. Allow a student to give directions to a partner to complete steps of the task.] **P** Have students play a game to simulate the nitrogen cycle (e.g., https://scied.ucar.edu/activity/nitrogen-cycle-game).

Multiple Means of Action and Expression	
Strategies	**Examples**
Provide graphic organizers and templates.	Provide an online interactive trophic pyramid (e.g., https://www.edumedia-sciences.com/en/media/548-trophic-pyramid). Provide a graphic organizer on ecological succession (e.g., http://science-class.net/archive/science-class/Ecology/succession.htm). [Individualization idea: Provide pictures and preprinted facts about each stage for students to place in the correct order on the graphic organizer.]

Table 7. Instructional strategy ideas using the UDL Principle: Multiple Means of Engagement

Multiple Means of Engagement	
Strategies	**Examples**
Provide a schedule.	Provide personal schedules with tangible symbols. Have students select the next activity on the schedule and set the visual timer to indicate how long the student has before a break. Use a first/then schedule (e.g., https://www.autismclassroomresources.com/visual-schedule-series-first-then/). [Individualization idea: Choose a schedule that provides maximum accessibility for each student—objects, picture symbols, color coded, assignment book, etc.] Provide checklist of tasks to complete in a specified order. [Individualization idea: Place words paired with pictures on a sheet with a "To Do" column and a "Finished" column using hook and loop tape.]
Vary the challenge and amount of information presented at a time.	Present a food chain or simple food web and introduce the terms "producer" and "consumers." Then, present the trophic levels and the concept of energy and matter across the trophic levels. [Individualization idea: Have students place pictures of plants and animals on models of the food chain, food web, and energy pyramid.]
Make connections to topics or activities that are motivating.	Create a service learning activity (e.g., https://www.paulakluth.com/readings/differentiating-instruction/article-differentiate-servicelearn/) such as researching the impact of human activities on climate, creating a pamphlet, and placing in public locations. [Individualization idea: Partner with general education peers to complete the project.]
Allow choices as possible.	Provide options for topics to research, options for pictures to use in projects, options for whom to partner with, etc.
Provide opportunities to work collaboratively with peers.	Provide opportunities for students to work in a general education classroom with peers when learning about unit topics or have peer tutors come into the special education classroom to work on a project about photosynthesis. [Individualization idea: Meet with peers and the student to discuss each person's strengths and plan how they can use those strengths while working in a cooperative group.]
Teach student self-regulation skills.	Work with the occupational or physical therapist to incorporate calming activities such as proprioceptive activities, vestibular activities, deep muscle work, oral activities, or tactile activities. Provide communication symbols to request a break or express feelings and model how to use them appropriately. Provide students with stress balls, finger fidgets, etc. Teach students how to self-reflect on their performance using scaffolding.

UDL Resources

- The National Center on Universal Design for Learning has a plethora of information on UDL along with examples and resources. www.udlcenter.org
- The UDL Curriculum Toolkit provides two applications for science. http://udl-toolkit.cast.org/p/applications/l1
- Perkins School for the Blind provides life science activities for students who are blind or have low vision. http://www.perkinselearning.org/accessible-science/activities/life-science
- This Perkins School for the Blind 20-minute video describes the techniques used to make science accessible for students who are blind and deaf-blind. https://www.youtube.com/watch?v=tpAejot1-Ec
- Symbaloo is a free online tool that allows an educator to create bookmarks using icons. It is easy to create and allows an educator to provide students links to sources of information that can be used for specific instructional units. www.symbaloo.com
- This site provides a brief description of Symbaloo and multiple ways to use the online tool. https://www.theedublogger.com/2014/04/09/11-ways-to-use-symbaloo-in-the-classroom/
- Perkins School for the Blind provides information on using tangible symbols to increase communication, create personal schedules, and provide choices. http://www.perkinselearning.org/videos/webcast/tangible-symbols

Section VII

Transference and Generalization of Concepts, Knowledge, and Skills

For learning to be meaningful for all students, including students with significant cognitive disabilities, it is important to intentionally make connections to future content, real-world application, and college and career readiness skills. For example, students can learn that the way they discover information through observation and investigation can also be used to problem solve daily living tasks. Additionally, the instruction of science concepts, knowledge, and skills may be the catalyst to developing other areas such as needed communication skills, reading/listening comprehension, mathematics skills, age-appropriate social skills, independent work behaviors, and skills in accessing support systems. Table 8 provides instructional ideas to help transfer and generalize concepts, knowledge, and skills and suggested opportunities to embed other skills into instruction.

Table 8. Transfer and Generalization Ideas

Area	Instruction	Opportunity to Embed Skills
Communication	When students are engaging in Scientific Inquiry and Engineering Design practices (see Section II), help students make the connections between constructing explanations (for science) and designing solutions (for engineering) and adequately explaining personal needs.	Use the context of the content area instruction to increase language skills, work on articulation, or access alternative and augmentative communication (AAC) systems.
Reading and Listening Comprehension	Provide content information through reading articles on science concepts (e.g., human activities and impact on climate) and connect to life-long learning through reading.	Work on comprehension skills when reading science articles. Work on use of assistive technology to independently read online text using a screen reader.
Mathematics	Teach creating and interpreting graphs when investigating climate patterns over time and connect to reading graphs in newspapers and online.	Provide practice on counting and determining quantities and patterns.
Age-Appropriate Social Skills	Make connections between the Crosscutting Concepts (e.g., a system can be described in terms of its components and their interactions) and real-life experiences (e.g., student is part of a system and must interact to make the system work).	Provide opportunities to work cooperatively in groups, including students without identified disabilities.
Independent Work Behaviors	Encourage and reinforce independent completion of tasks to build independent work skills.	Use this time to have the student work on following task completion checklists independently.
Skills in Accessing Support Systems	Encourage students to ask appropriately for assistance from peers and adults when researching information on the effect natural disasters have on organisms.	Use this time to have the student work on behavior and communication skills.

Section VIII

Tactile Maps and Graphics

The maps and graphics guidelines will help create tactile versions of instructional maps, diagrams, models, and timelines to use with students who are blind or deaf-blind. The tactile maps and graphics may be beneficial to other students as well. A tactile graphic is a representation of a graphic (e.g., picture, drawing, diagram, map, etc.) in a form that provides access through touch. It is not an exact copy of the graphic. The section provides basic guidance and links to more comprehensive resources.

Importance of Tactile Maps and Graphics

It is important to provide tactile graphics for young readers (BANA, 2010). It helps students understand and gain information when presented with science concepts, knowledge, and skills. Science instruction often presents diagrams (e.g., water cycle) and two-dimensional models of living and nonliving things (e.g., model of cell) to teach the related concepts. The following guidance includes information to build upon when creating tactile graphics.

Tactile Graphic Guidance

1. **Determine need for graphic:** When encountering graphics in instructional materials, determine if the graphic is essential to understanding the concept. The Braille Authority of North America (2010) provides a decision tree to help in this determination. It can be accessed online at http://www.brailleauthority.org/tg/web-manual/index.html by selecting “Unit 1 Criteria for Including a Tactile Graphic.”
2. **Consult with the local educator trained to work with students with visual impairments.**
3. **Determine the essential information in the graphic.** Read the surrounding information and the caption to determine which information in the graphic to exclude. For example, a model to illustrate the cell wall, nucleus, chloroplast, and vacuole would not need to include the nuclear membrane, Golgi body, and ribosomes.
4. **Reduce unnecessary detail in the graphic.** Identify details that are not necessary for interpreting the information in the graphic. For example, a model of the water cycle may show crevices on the mountains, leaves on a tree, and waves in an ocean. Eliminate unnecessary details, as they are difficult to interpret tactilely.
5. **Remove frames or image outlines if they serve no purpose.** Ensure that all lines are necessary (e.g., the lines showing the river), and remove any that are not (e.g., ripples in the water).
6. **Modify the size of the graphic.** Modify the graphic as needed to reduce clutter and allow a blank space between adjacent textures. Additionally, consider the size of the student’s hand.
7. **Use solid shapes as feasible.** When solid shapes do not clearly represent the information, use clear solid lines.
8. **Systematically teach exploration and interpretation of tactile graphics.** Systematic instruction and repetition are important when teaching a student to understand a tactile graphic. Pairing the tactile graphic with a 3-dimensional object may help (e.g., pair a raised line drawing of a plant, an example of plants and their parts, with a real plant).

Specific Graphic Type Guidance

Following is information for specific types of graphics that may support instruction in science.

Graphic Organizers/Concept Maps

- It is best to present information to compare or make connections using a tactile graphic. A tactile graphic presents the information in a spatial display and aids in comparison better than a list.

Diagrams/Models

- Limit the number of areas, lines, and labels. Having more than five makes interpretation difficult.
- Consider pairing a tactile graphic with a 3-dimensional model.

Timelines

- Present timelines in the same direction every time (i.e., horizontal or vertical).

Maps

- Distinguish water from land using a consistent background texture for the water.
- Align the direction of the compass rose arrows with the lines of longitude and latitude on the map.

Creating Tactile Graphics

Following are some ways to create tactile graphics. Additional information can be found at www.tactilegraphics.org.

Commercial products:

- Capsule paper or swell paper for printing, and
- Thermoform.

Textured shapes can be made from:

- Sticky back textured papers found at craft stores,
- Corrugated cardboard,
- Fabric with texture (e.g., corduroy, denim),
- Silk leaves,
- Cork,
- Felt,
- Vinyl,
- Mesh tape (used for drywall), and
- Sandpaper.

Raised lines can be made from:

- Glue (best not to use water-based glue), and
- Wax pipe cleaners.

Resources

- The American Foundation for the Blind provides basic principles for preparing tactile graphics. http://www.afb.org/info/solutions-forum/electronic-files-and-research-work-group/tactile-graphics/345
- The Texas School for the Blind and Visually Impaired provides basic principles for preparing tactile graphics, element arrangement on a tactile graphic, resources for preparing quality graphics, etc. http://www.tsbvi.edu/graphics-items/1465-basic-principles-for-preparing-tactile-graphics
- Perkins School for the Blind has tips for reading tactile graphics in science with a focus on state assessment. http://www.perkinselearning.org/accessible-science/blog/tips-reading-tactile-graphics-science-focus-state-assessment

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

Joint Project of the Braille Authority of North America and the Canadian Braille Authority L'Autorite Canadienne du Braille. (2011). *Guidelines and Standards for Tactile Graphics, 2010.* Retrieved February 19, 2014, from Braille Authority of North America: http://www.brailleauthority.org/tg.

CAST (2011). *Universal Design for Learning Guidelines version 2.0.* Wakefield, MA.

Marzano, R. J. (2004). *Building Background Knowledge for Academic Achievement*. Alexandria: ASCD.

Sprenger, M. (2013). *Teaching the Critical Vocabulary of the Common Core*. Alexandria: ASCD.

Picture Citations

https://pixabay.com/en/wave-smashing-foam-spray-sea-2211925/ CC0 1.0
https://pixabay.com/en/earth-blue-planet-globe-planet-11015/ CC0 1.0
https://openclipart.org/detail/289930/water-cycle CC0 1.0
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[2] All resources provided for this module only. Mention does not imply endorsement, recommendation, or approval by the Tennessee Department of Education.

Prepared by edCount, LLC in collaboration with Educational Testing Service as part of the TCAP/Alt Science and Social Studies contract.