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: What would happen to a bean plant if it did not get any water? What would happen to the wolves in an ecosystem if the rabbits and other small animals left? Which organism in a food chain has the most energy? Why do offspring resemble both parents? What types of groundcover can be used to stabilize a hillside, but not disturb native plant or animal species?

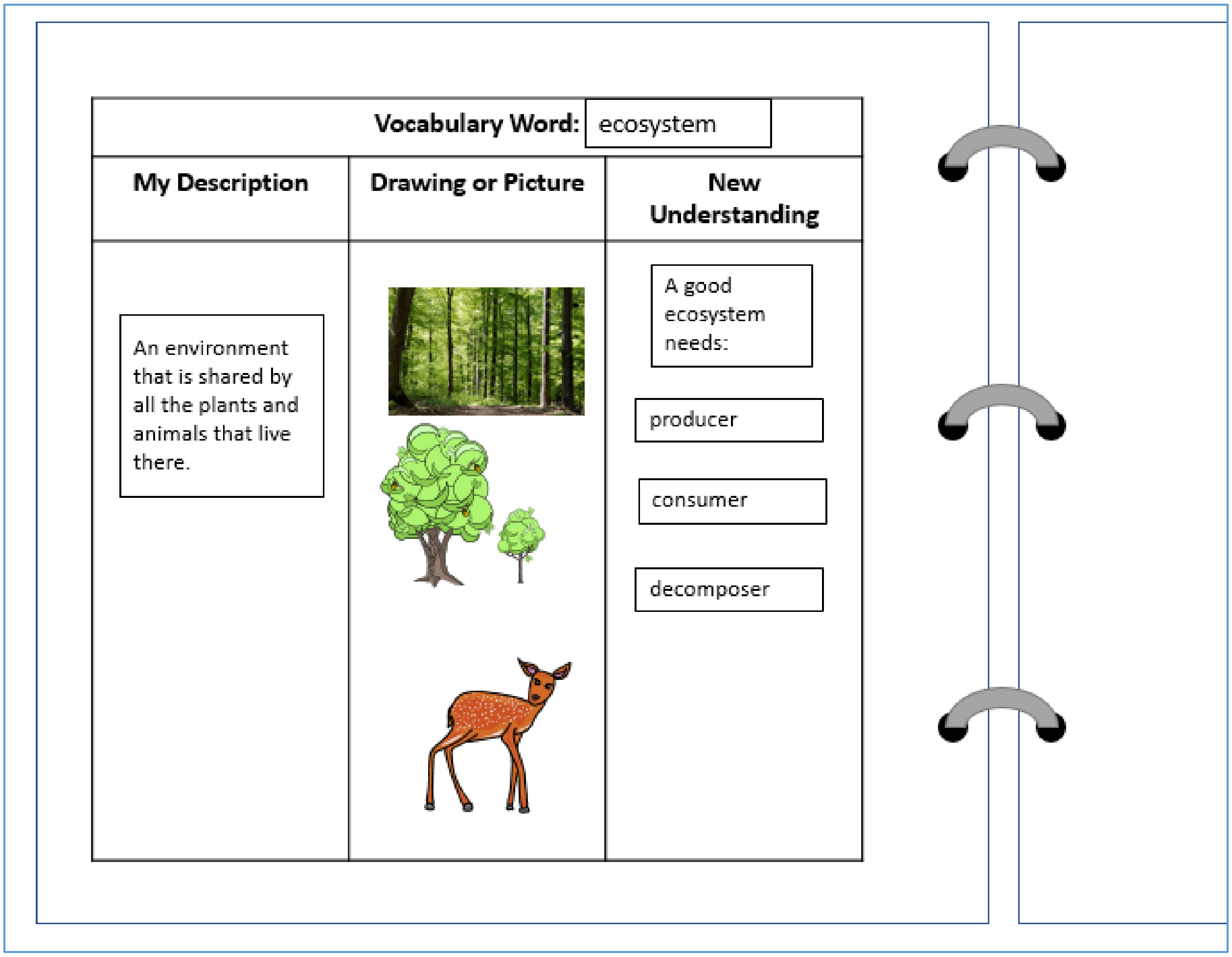
- Developing and using models.
  Examples: Use a model of photosynthesis (without chemical symbols) to understand and explain the flow of oxygen and carbon dioxide. Develop a model to describe a food chain or food web in an ecosystem. Use a model of mitosis to demonstrate how a single parent cell produces two identical daughter cells. Design a self-contained ecosystem that cycles oxygen and carbon dioxide. Use a model to test interactions concerning the functioning of a natural system. Use appropriate tools and measurements to construct a model of energy transfer between producers and consumers in an ecosystem.

- Planning and carrying out investigations.
  Examples: Design and conduct an investigation to find what plants need to live and grow (e.g., test the effect of saturation on a plant; have students collect a soil sample, weigh and dry a soil sample, and determine the moisture content of the sample.). Design investigations about particular phenomena, such as the growth of plants. Perform investigations where the input of light energy is manipulated.

- Analyzing and interpreting data.
  Examples: Use data to determine if a specific animal is a predator or prey. Analyze a predator-prey relationship graph to determine what happens when the prey population decreases. Collect data during investigations and observations of simulations; construct an explanation for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

- Using mathematics and computational thinking.
  Examples: Measure and chart a plant as it grows. Count the number of consumers in a food web. Use information presented in various modes (e.g., graphs, diagrams, photographs, text, mathematical, verbal) to classify types of relationship based on trends in two species' population

Figure 1. Example Science Vocabulary Notebook Page



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 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 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).	Provide tactile representation of the carbon/oxygen cycle (see Section VIII Tactile Maps and Graphics for guidance) and use each time the student is presented with information on photosynthesis and the cycling of matter. [Individualization idea: Pair each part of the graphic with what it represents (e.g., graphic of sun to feeling the heat of the sun; seeing the light from a lamp; touching a live plant; feeling breath for carbon dioxide; breeze for oxygen).] Introduce cellular respiration using a kinesthetic activity (e.g., http://www.perkinselearning.org/accessible-science/activities/cellular-respiration-kinesthetic-activity). Present the "Mitosis Hand Jive," hand movements that demonstrate how cells divide during mitosis (e.g., https://www.youtube.com/watch?v=PYIMWgyQVtg). Pair various animal sounds with pictures when teaching about predators and prey. [Individualization idea: Provide the sound of a predator and a prey on a dual switch that includes pictures and the label of each animal. Have the student select which animal is a predator or a prey.]
Model content through pictures, dramatization, videos, etc.	Have students watch a video on photosynthesis (e.g., https://www.youtube.com/watch?v=68b1HAIfX08 or https://www.youtube.com/watch?v=uixA8ZXx0KU). Show a video on organisms and ecosystems (e.g., https://www.youtube.com/watch?v=bJEToQ49Yjc&t=122s). Share an animation of the carbon cycle (e.g., http://www.kscience.co.uk/animations/carbon_cycle.htm). [Individualization idea: Re-create the model of the carbon cycle by taping pictures of the stages on the floor and using painter's tape for the arrows. Have students move from one stage to the next as you describe what happens.] Have students watch videos on mitosis and meiosis (e.g., https://www.youtube.com/watch?v=f-ldPgEfAHI, https://www.youtube.com/watch?v=VzDMG7ke69g, and https://www.youtube.com/watch?v=VzDMG7ke69g&t=28s).
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: http://www.cehd.umn.edu/nceo/teleconferences/tele14/CourtadeFlowers.pdf). **V/H/P**

Multiple Means of Representation	
Strategies	**Examples**
	Present models of food chains, food webs, and energy pyramids to explain the flow of energy. [Individualization idea: Use 3-D representations of producers, consumers (primary and secondary), and decomposers and have students place in small baskets to represent food chains. To label the baskets, place a picture of the sun and a plant in the consumer basket, a picture of plants in the primary consumer basket, a picture of herbivores in the secondary consumer basket, and a picture of dirt in the decomposer basket.] **V**
Provide appropriate and accessible text on the content for students to listen to or read.	Paraphrase information from a textbook (e.g., Sunlight is the source of energy for plants. Plants are called producers. Plants turn sunlight into sugar, which can be used for food. Animals eat plants or other animals that eat plants to get the energy the plant has produced. Animals are called consumers.) on large sticky notes (e.g., Place the sticky note over the original text, leaving the graphics. 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** [Individualization idea: Have a peer read the paraphrased text to the student and/or have the student read repetitive words such as "plants."] Record paraphrased information about energy flow or cycling of matter in an ecosystem and store online using a program such as https://recordmp3online.com/. **V** Provide access to the recordings using an icon-based bookmark program such as Symbaloo (www.symbaloo.com). Provide online text that can be read to the students using a screen reader (e.g., https://www.ck12.org/c/life-science/importance-of-mammals/lesson/Importance-of-Mammals-MS-LS/?referrer=concept_details or https://www.ck12.org/earth-science/roles-in-an-ecosystem/lesson/Roles-in-an-Ecosystem-MS-ES/?referrer=concept_details).
Teach information using songs.	Teach and reinforce concepts using songs on plant needs (e.g., https://www.youtube.com/watch?v=dUBIQ1fTRzI), mitosis (e.g., https://www.youtube.com/watch?v=f7Dmhfo7XXA), etc. [Individualization idea: Pair written words to the song and sign as other students are listening to the song.] **H**

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.	Read a book about animal parts online (e.g., http://bookbuilder.cast.org/view.php?op=view&book=89446&page=1). [Individualization idea: Create a personalized book for the student using CAST UDL Book Builder (http://bookbuilder.cast.org/create.php, requires user to set up free account). For example, write a short book about the carbon/oxygen cycle using a picture of the student, the student's yard, etc., to illustrate the book.] Have the student complete online interactive activities (e.g., food chains: http://www.glencoe.com/sites/common_assets/science/virtual_labs/CT06/CT06.swf, http://www.sheppardsoftware.com/content/animals/kidscorner/games/foodchaingame.htm or food web: http://teacher.scholastic.com/activities/explorer/ecosystems/be_an_explorer/map/line_experiment14.swf).
Allow for instructional materials that can be modified to provide access.	Have students complete online interactions among organisms' resources (e.g., http://www.sheppardsoftware.com/content/animals/kidscorner/games/foodchaingame.htm). [Individualization idea: Have student use tracker ball or other adapted mouse to make selections. Read information and choices to the student.] Have students build a bottle ecosystem (e.g., http://www.thegeoexchange.org/carboncycle/projects/bottle-ecosystem.html) to develop an understanding of the carbon cycle. [Individualization idea: Print, cut, and paste the picture directions to create a checklist for the student to follow. Have student work on range of motion and crossing midline while reaching for materials.]
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**
Provide simulation activities.	Simulate the flow of energy in an ecosystem by having students represent various producers, consumers, and decomposers (e.g., http://www.perkinselearning.org/accessible-science/activities/hunger-games). Simulate the carbon cycle by having students play the role of carbon atoms (e.g., https://betterlesson.com/lesson/639294/carbon-and-nitrogen-cycles-1-of-2)

Multiple Means of Action and Expression	
Strategies	**Examples**
Provide graphic organizers and templates.	Have students sort examples of producers, consumers, and decomposers. Complete a model of the flow of energy through an ecosystem using an energy pyramid. [Individualization idea: Provide a template and line drawings of the organisms to place in the energy pyramid. Provide more producers, fewer primary consumers, and one secondary consumer.]

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

Multiple Means of Engagement	
Strategies	**Examples**
Provide a schedule and visual timer.	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/). Provide checklist of tasks to complete in a particular order. [Individualization idea: Present task/steps with pictures of the student completing each.]
Vary the challenge and amount of information presented at a time.	Provide key concepts on predatory, competitive, and symbiotic relationships in an ecosystem for the student to study independently and at home. [Individualization idea: Create short video clips of the educator or a peer sharing the key concepts that can be played on a tablet.]
Make connections to topics or activities that are motivating.	Show a short video that relates to a concept (e.g., photosynthesis) from a popular movie (e.g., The Lorax— https://www.youtube.com/watch?v=pc9ueZYUdqA). Use animals that are interesting to the student when studying the food chain/web.
Allow choices as possible.	Allow students to choose whether to look at/listen to a book, watch a video, or play a computer game about the flow of energy during independent work time.
Provide opportunities to work collaboratively with peers.	Provide opportunities for students to work in a general education classroom with peers when learning about photosynthesis or have peer tutors come into the special education classroom to work on a project about photosynthesis.
Teach student self-regulation skills.	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.

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 asking questions and communicating information to future work environments (e.g., asking for details about a job task and ability to communicate information to a supervisor).	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 information through reading books and articles on science concepts (e.g., energy flow and cycling of matter) while working on reading comprehension.	Provide practice on communication skills when students are answering questions about information in the book or article. Work on fine motor skills while turning pages or range of motion by pointing to pictures.
Mathematics	Teach measuring during an investigation on plant needs.	Provide practice on number identification and relative quantity (e.g., Which is more?).
Age-Appropriate Social Skills	Make connections between the Crosscutting Concepts and real-life experiences showing the cause-and-effect relationships of their behaviors and how those can be used to predict outcomes.	Provide opportunities to work along same age peers to practice age-appropriate social skills and serve a vital role in the group.
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 accessing information on predator-prey relationships.	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

- Creating Tactile Graphics, created by the High Tech Center Training Unit, provides basic principles of tactile graphics, characteristics of good tactile graphics, the planning process, guidelines for designs, and more. http://www.htctu.net/trainings/manuals/alt/Tactile_Graphics.pdf
- 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

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Picture Citations

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