Developing an Engineering Design Challenge (Grade 4)

Developing an Engineering Design Challenge

STEM professions require individuals to apply their content knowledge to unique circumstances and to solve problems using creativity and innovation. When engineers are presented with a problem, they research to determine if the problem has occurred before (language arts connection) and what innovations have been made in the past (historical connection). Then, the engineer will use engineering practices to develop a solution that applies science and math knowledge. Engineering design challenges can be created for a specific standard or aligned with multiple standards and subject areas. Cross-disciplinary instruction introduces concepts and skills that could be linked from two or more disciplines to highlight connections and deepen understanding. Integrated learning can help students see the connection across content areas and braid that understanding together to create a solution to a problem using the engineering design process.

Purpose of this Tool:

This tool supports educators in developing cross-curricular engineering design challenges anchored in the science standards. While engineering practices are embedded in the Texas Essential Knowledge and Skills (TEKS) for science, engineering design challenges can draw from multiple subject areas. By integrating content across disciplines, students apply their knowledge in meaningful ways to solve a real-world problem.

This tool includes the following components:

1. A graphic organizer to identify targeted standards
2. A content crosswalk to help educators identify potential connections for an engineering design challenge
3. STEM career highlights for each student expectation

Engineering Design Practices:

When developing an engineering design challenge, it is important to anchor the challenge in TEKS. The students will use the engineering practices TEKS paired with the science content TEKS when solving the engineering design challenge. The first strand in the science TEKS outlines the scientific and engineering practices for the grade level/courses. Engineering practices refer to the methods, techniques, and standards that engineers use to ensure their work is efficient, reliable, safe, and meets the intended requirements. To create a cohesive learning experience, educators should integrate scientific and engineering practices with content. Embedding these practices across the content areas as part of engineering design challenges provides students with the context in which to ask questions, develop models, and analyze data that supports critical thinking and problem-solving skills in real-world scenarios.

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Engineering Design Process:

The engineering design process is a systematic way of thinking, used to teach and apply concepts and skills in an integrated manner. Students engage with concepts from multiple disciplines while using design thinking to develop a solution to an open-ended, authentic problem. Learning from failure is a natural part of the iterative process. There are numerous engineering design process models; however, they share foundational practices that include identifying questions or defining problems, imagining solutions, brainstorming ideas, planning, creating, testing, and improving a design.

Engineering-Related TEKS:

In grade 4 science, the following standards include engineering practices and could be paired with engineering design challenges. The student is expected to:

Science.4.1.A ask questions and define problems based on observations or information from text, phenomena, models, or investigations
Science.4.1.B use scientific practices to plan and conduct descriptive investigations and use engineering practices to design solutions to problems
Science.4.1.G develop and use models to represent phenomena, objects, and processes or design a prototype for a solution to a problem
Science.4.2.D evaluate a design or object using criteria
Science.4.4.A explain how scientific discoveries and innovative solutions to problems impact science and society
Science.4.4.B research and explore resources such as museums, libraries, professional organizations, private companies, online platforms, and mentors employed in a science, technology, engineering, and mathematics (STEM) field to investigate STEM careers
Science.4.5.A identify and use patterns to explain scientific phenomena or to design solutions

Communication is also part of the engineering design process. Claim-Evidence-Reasoning (CER) is a discussion structure commonly used by scientists and engineers to engage in collaborative discussions with peers. While both scientists and engineers use the CER structure, they use it for different purposes. Scientists tend to focus on asking questions and analyzing patterns, while engineers tend to focus on solving problems. The following student expectations demonstrate the knowledge and skills students apply to communicate their thinking. The student is expected to:

Science.4.3.A develop explanations and propose solutions supported by data and models
Science.4.3.B communicate explanations and solutions individually and collaboratively in a variety of settings and formats
Science.4.3.C listen actively to others' explanations to identify relevant evidence and engage respectfully in scientific discussion

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Component 1: Integration Planning Graphic Organizer

The *Integration Planning Graphic Organizer* can be used in conjunction with the Integrated Content Crosswalk for STEM Education to organize the standards and subject areas incorporated into an engineering design challenge. The graphic organizer serves as a workspace to capture ideas of possible connections, but not all spaces need to be filled. Many factors will influence the selection of standards during an engineering design challenge. Instructional materials, district scope and sequences, student age, and other factors that inform instructional decisions are some examples.

On the next page is an example of a grade 5 science engineering design challenge developed using the components of this tool. In this example, the graphic organizer has been completed with information from the Integrated Content Crosswalk for STEM Education. There are many ways to approach developing an engineering design challenge. An easy way to start is to select your science content standard, then identify the problem that needs to be solved, and what engineering practices will be used when solving the problem. The highlighted standard below is the content standard used as an anchor for this challenge. The engineering practices that align with this challenge are Science.5.1.G and Science.5.4.A.

Highlighted Standards from the Example:

The student is expected to:
Science.5.6.A compare and contrast matter based on measurable, testable, or observable physical properties, including mass, magnetism, relative density (sinking and floating using water as a reference point), physical state (solid, liquid, gas), volume, solubility in water, and the ability to conduct or insulate thermal energy and electric energy
Science.5.1.G develop and use models to represent phenomena, objects, and processes or design a prototype for a solution to a problem
Science.5.4.A how scientific discoveries and innovative solutions to problems impact science and society

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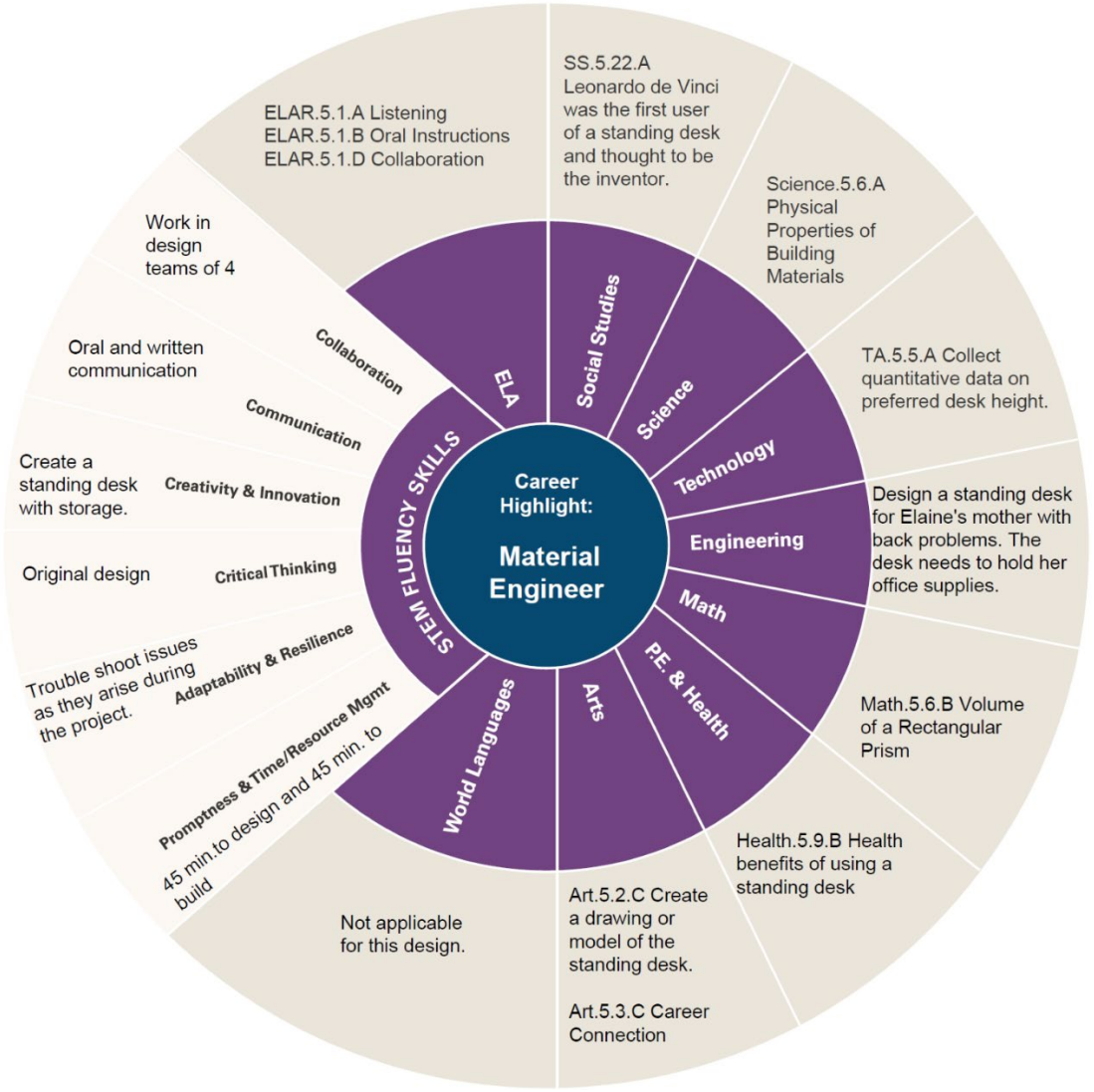

Engineering Design Challenge: Design a standing desk for Elaine's mother who has back problems. The desk needs to hold her office supplies.

Core Subject Area Connection Summary:

Science.5.6.A Compare and contrast physical properties of building materials

Math.5.6.B Calculate the volume of the standing desk (Rectangular Prism)

SS.5.22.A Read about Leonardo de Vinci who was the first user of a standing desk and thought to be the inventor

ELAR TEKS Support the STEM Fluency Skills:

ELAR.5.1.A and 5.1.B Listen to others and provide oral Instructions (Communication)

ELAR.5.1.D Work in groups (Collaboration)

Enrichment Area Connection Summary:

TA.5.5.A Collect quantitative data on preferred desk height

Health.5.9.B Identify health benefits of using a standing desk

Art.5.2.C Create a drawing or model of the standing desk

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Component 2: Integrated Content Crosswalk for STEM Education

The Integrated Content Crosswalk for STEM Education section is a resource designed to help teachers identify connections between student expectations across the required curricula. It is important to note that this tool offers suggestions. Educators may use the suggestions in the crosswalk as a starting place for selecting student expectations across disciplines for an engineering design challenge. Student expectations in an integrated content crosswalk will vary and should align with the design challenge. The Integration Planning Graphic Organizer example provided for grade 5 includes the student expectations from the crosswalk, as well as additional standards from health and art. The boxes on the chart excerpt below indicate the student expectations that were used in the previous example on the graphic organizer.

In a STEM career, professionals must communicate throughout a design process. Students will practice language skills during engineering design challenges by using written and oral communication, research, questioning, and synthesizing information. Students may also use technology to create, develop, and communicate their ideas. The standards aligned to each project will change depending on what students are doing in the design challenge.

Science Student Expectation	Math Connection	Social Studies Connection	Reading Language Arts Connection	Technology Applications Connection
Science.5.6.A compare and contrast matter based on measurable, testable, or observable physical properties, including mass, magnetism, relative density (sinking and floating using water as a reference point), physical state (solid, liquid, gas), volume, solubility in water, and the ability to conduct or insulate thermal energy and electric energy **Career Highlights:** Materials Engineers, Machinists, Service Unit Operators	**Math.5.1.E** create and use representations to organize, record, and communicate mathematical ideas **Math.5.6.A** recognize a cube with side length of one unit as a unit cube having one cubic unit of volume and the volume of a three-dimensional figure as the number of unit cubes (n cubic units) needed to fill it with no gaps or overlaps if possible **Math.5.6.B** determine the volume of a rectangular prism with whole number side lengths in problems related to the number of layers times the number of unit cubes in the area of the base	**SS.5.22.A** identify the accomplishments of notable individuals in the fields of science and technology such as Benjamin Franklin and Thomas Edison	**ELAR.5.1.B** follow, restate, and give oral instructions that include multiple action steps **ELAR.5.1.D** work collaboratively with others to develop a plan of shared responsibilities **ELAR.5.13.A** generate questions on a topic for formal and informal inquiry	**TA.5.5.A** identify and collect quantitative and qualitative data with digital tools

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Component 3: Career Highlights

The career highlights section is listed below each science student expectation in the Integrated Content Crosswalk for STEM Education. The career highlights are designed to provide career connections to the science content being taught. On the *Integrated Content Crosswalk*, each science standard has three career connections that support the incorporation of scientific and engineering practices for investigating STEM careers. The careers highlighted use the science content regularly by STEM professionals in their careers. The career highlights show science content that is regularly used by STEM professionals in the identified careers. The Texas Workforce Commission and O*NET provide the labor data information. Connecting engineering design challenges to careers promotes career awareness and provides relevance for learning content.

Getting Started:

To begin developing your own cross-curricular engineering design challenge, start by selecting a science content standard that aligns with your instructional goals. Use the Integration Planning Graphic Organizer in conjunction with the Integrated Content Crosswalk for STEM Education to identify meaningful connections across subject areas and incorporate relevant student expectations. Consider which engineering practices will be used to solve the real-world problem presented in the engineering design challenge. Leverage the career highlights to introduce students to STEM professions and make learning more relevant. As you plan, remember to adapt this tool to fit your students' needs, available resources, and instructional context.

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Integrated Content Crosswalk for STEM Education and Career Highlights:

Science Student Expectation	Math Connection	Social Studies Connection	Reading Language Arts Connection	Technology Applications Connection
Science.4.6.A classify and describe matter using observable physical properties, including temperature, mass, magnetism, relative density (the ability to sink or float in water), and physical state (solid, liquid, gas) **Career Highlights:** Materials Engineers, Machinists, Service Unit Operators	**Math.4.1.E** create and use representations to organize, record, and communicate mathematical ideas **Math.4.8.A** identify relative sizes of measurement units within the customary and metric systems **Math.4.8.B** convert measurements within the same measurement system, customary or metric, from a smaller unit into a larger unit or a larger unit into a smaller unit when given other equivalent measures represented in a table		**ELAR.4.1.D** work collaboratively with others to develop a plan of shared responsibilities	**TA.4.5.A** classify numerical and non-numerical data
Science.4.6.B investigate and compare a variety of mixtures, including solutions that are composed of liquids in liquids and solids in liquids **Career Highlights:** Engineers, Registered Nurses - RN, Chemical Plant Operators	**Math.4.1.F** analyze mathematical relationships to connect and communicate mathematical ideas		**ELAR.4.1.D** work collaboratively with others to develop a plan of shared responsibilities	**TA.4.5.A** classify numerical and non-numerical data **TA.4.5.B** identify and collect data by using various search strategies, including two or more keywords within specific parameters

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Science Student Expectation	Math Connection	Social Studies Connection	Reading Language Arts Connection	Technology Applications Connection
Science.4.6.C demonstrate that matter is conserved when mixtures such as soil and water or oil and water are formed **Career Highlights:** Engineers, Registered Nurses - RN, Chemical Plant Operators			**ELAR.4.1.B** follow, restate, and give oral instructions that involve a series of related sequences of action **ELAR.4.1.D** work collaboratively with others to develop a plan of shared responsibilities **ELAR.4.13.A** generate questions on a topic for formal and informal inquiry	
Science.4.7.A plan and conduct descriptive investigations to explore the patterns of forces such as gravity, friction, or magnetism in contact or at a distance on an object **Career Highlights:** Engineers, Physicists, Airline Pilots, Copilots, and Flight Engineers	**Math.4.1.E** create and use representations to organize, record, and communicate mathematical ideas **Math.4.1.F** analyze mathematical relationships to connect and communicate mathematical ideas **Math.4.5.B** represent problems using an input-output table and numerical expressions to generate a number pattern that follows a given rule representing the relationship of the values in the resulting sequence and their position in the sequence	**SS.4.18.A** identify famous inventors and scientists such as Millie Hughes-Fulford and their contributions	**ELAR.4.1.B** follow, restate, and give oral instructions that involve a series of related sequences of action **ELAR.4.1.D** work collaboratively with others to develop a plan of shared responsibilities **ELAR.4.13.A** generate questions on a topic for formal and informal inquiry	**TA.4.1.B** identify patterns in story problems and make predictions based on the pattern **TA.4.5.A** classify numerical and non-numerical data **TA.4.6.A** use digital tools to transform and make inferences about data to answer a question

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Science Student Expectation	Math Connection	Social Studies Connection	Reading Language Arts Connection	Technology Applications Connection
Science.4.8.A investigate and identify the transfer of energy by objects in motion, waves in water, and sound **Career Highlights:** Energy Engineer, Fuel Cell Engineers, Sound Engineering Technicians	**Math.4.1.A** apply mathematics to problems arising in everyday life, society, and the workplace **Math.4.1.C** select tools, including real objects, manipulatives, paper and pencil, and technology as appropriate, and techniques, including mental math, estimation, and number sense as appropriate, to solve problems **Math.4.1.F** analyze mathematical relationships to connect and communicate mathematical ideas		**ELAR.4.1.D** work collaboratively with others to develop a plan of shared responsibilities **ELAR.4.6.F** make inferences and use evidence to support understanding **ELAR.4.13.A** generate questions on a topic for formal and informal inquiry	**TA.4.5.A** classify numerical and non-numerical data **TA.4.5.B** identify and collect data by using various search strategies, including two or more keywords within specific parameters **TA.4.6.A** use digital tools to transform and make inferences about data to answer a question
Science.4.8.B identify conductors and insulators of thermal and electrical energy **Career Highlights:** Electrical Engineering Technicians, Electricians, Nanosystems Engineers			**ELAR.4.1.D** work collaboratively with others to develop a plan of shared responsibilities **ELAR.4.6.F** make inferences and use evidence to support understanding **ELAR.4.13.A** generate questions on a topic for formal and informal inquiry	

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Science Student Expectation	Math Connection	Social Studies Connection	Reading Language Arts Connection	Technology Applications Connection
Science.4.8.C demonstrate and describe how electrical energy travels in a closed path that can produce light and thermal energy **Career Highlights:** Electrical Engineering Technicians, Electricians, Signal and Track Switch Repairers			**ELAR.4.1.B** follow, restate, and give oral instructions that involve a series of related sequences of action **ELAR.4.1.D** work collaboratively with others to develop a plan of shared responsibilities **ELAR.4.13.A** generate questions on a topic for formal and informal inquiry	
Science.4.9.A collect and analyze data to identify sequences and predict patterns of change in seasons such as change in temperature and length of daylight **Career Highlights:** Atmospheric and Space Scientists, Geoscientists, Hydrologists	**Math.4.1.E** create and use representations to organize, record, and communicate mathematical ideas **Math.4.1.F** analyze mathematical relationships to connect and communicate mathematical ideas	**SS.4.6.A** identify, locate, and describe the physical regions of Texas (Mountains and Basins, Great Plains, North Central Plains, Coastal Plains), including their characteristics such as landforms, climate, vegetation, and economic activities **SS.4.7.A** explain the geographic factors such as landforms and climate that influence patterns of settlement and the distribution of population in Texas, past and present	**ELAR.4.6.B** generate questions about text before, during, and after reading to deepen understanding and gain information **ELAR.4.6.E** make connections to personal experiences, ideas in other texts, and society **ELAR.4.6.F** make inferences and use evidence to support understanding	**TA.4.1.B** identify patterns in story problems and make predictions based on the pattern **TA.4.5.A** classify numerical and non-numerical data **TA.4.6.A** use digital tools to transform and make inferences about data to answer a question

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Science Student Expectation	Math Connection	Social Studies Connection	Reading Language Arts Connection	Technology Applications Connection
Science.4.9.B collect and analyze data to identify sequences and predict patterns of change in the observable appearance of the Moon from Earth **Career Highlights:** Astronomers, Aerospace Engineers, Atmospheric and Space Scientists	**Math.4.1.A** select tools, including real objects, manipulatives, paper and pencil, and technology as appropriate, and techniques, including mental math, estimation, and number sense as appropriate, to solve problems **Math.4.1.E** create and use representations to organize, record, and communicate mathematical ideas		**ELAR.4.6.D** create mental images to deepen understanding **ELAR.4.6.E** make connections to personal experiences, ideas in other texts, and society **ELAR.4.6.F** make inferences and use evidence to support understanding	**TA.4.5.A** classify numerical and non-numerical data **TA.4.6.A** use digital tools to transform and make inferences about data to answer a question
Science.4.10.A describe and illustrate the continuous movement of water above and on the surface of Earth through the water cycle and explain the role of the Sun as a major source of energy in this process **Career Highlights:** Atmospheric and Space Scientists, Geoscientists, Hydrologists			**ELAR.4.13.A** generate questions on a topic for formal and informal inquiry **ELAR.4.13.C** identify and gather relevant information from a variety of sources **ELAR.4.13.E** demonstrate understanding of information gathered	

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Science Student Expectation	Math Connection	Social Studies Connection	Reading Language Arts Connection	Technology Applications Connection
Science.4.10.B model and describe slow changes to Earth's surface caused by weathering, erosion, and deposition from water, wind, and ice **Career Highlights:** Park Naturalists, Geographers, Geoscientists			**ELAR.4.1.D** work collaboratively with others to develop a plan of shared responsibilities **ELAR.4.13.A** generate questions on a topic for formal and informal inquiry	
Science.4.10.C differentiate between weather and climate **Career Highlights:** Atmospheric and Space Scientists, Geoscientists, Hydrologists	**Math.4.1.F** analyze mathematical relationships to connect and communicate mathematical ideas **Math.4.9.A** represent data on a frequency table, dot plot, or stem-and-leaf plot marked with whole numbers and fractions	**SS.4.7.A** explain the geographic factors such as landforms and climate that influence patterns of settlement and the distribution of population in Texas, past and present	**ELAR.4.13.A** generate questions on a topic for formal and informal inquiry	
Science.4.11.A identify and explain advantages and disadvantages of using Earth's renewable and nonrenewable natural resources such as wind, water, sunlight, plants, animals, coal, oil, and natural gas **Career Highlights:** Geoscientists, Mining & Geological Engineers, Anthropologists & Archeologists		**SS.4.8.A** describe ways people have adapted to and modified their environment in Texas, past and present, such as timber clearing, agricultural production, wetlands drainage, energy production, and construction of dams **SS.4.11.B** explain how physical geographic factors such as climate and natural resources have influenced the location of economic activities in Texas	**ELAR.4.6.G** evaluate details read to determine key ideas **ELAR.4.7.C** use text evidence to support an appropriate response **ELAR.4.13.A** generate questions on a topic for formal and informal inquiry	

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Science Student Expectation	Math Connection	Social Studies Connection	Reading Language Arts Connection	Technology Applications Connection
Science.4.11.B explain the critical role of energy resources to modern life and how conservation, disposal, and recycling of natural resources impact the environment **Career Highlights:** Engineers, Agricultural Engineers, Conservation Scientists	**Math.4.1.E** create and use representations to organize, record, and communicate mathematical ideas **Math.4.1.G** display, explain, and justify mathematical ideas and arguments using precise mathematical language in written or oral communication **Math.4.9.A** represent data on a frequency table, dot plot, or stem-and-leaf plot marked with whole numbers and fractions	**SS.4.8.B** explain reasons why people have adapted to and modified their environment in Texas, past and present, such as the use of natural resources to meet basic needs, facilitate transportation, and enhance recreational activities **SS.4.8.C** compare the positive and negative consequences of human modification of the environment in Texas, past and present	**ELAR.4.7.C** use text evidence to support an appropriate response **ELAR.4.13.A** generate questions on a topic for formal and informal inquiry **ELAR.4.13.H** use an appropriate mode of delivery, whether written, oral, or multimodal, to present results	
Science.4.11.C determine the physical properties of rocks that allow Earth's natural resources to be stored there **Career Highlights:** Geoscientists, Mining & Geological Engineers, Hydrologists			**ELAR.4.6.G** evaluate details read to determine key ideas **ELAR.4.13.A** generate questions on a topic for formal and informal inquiry **ELAR.4.13.C** identify and gather relevant information from a variety of sources	

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Science Student Expectation	Math Connection	Social Studies Connection	Reading Language Arts Connection	Technology Applications Connection
Science.4.12.A investigate and explain how most producers can make their own food using sunlight, water, and carbon dioxide through the cycling of matter **Career Highlights:** Soil & Plant Scientists, Biologists, Farmworkers & Laborers, Crop, Nursery, & Greenhouse			**ELAR.4.1.D** work collaboratively with others to develop a plan of shared responsibilities **ELAR.4.6.F** make inferences and use evidence to support understanding **ELAR.4.13.A** generate questions on a topic for formal and informal inquiry	**TA.4.3.A** explain the importance of and demonstrate personal skills and behaviors, including problem solving and questioning, effective communication, following directions, mental agility, and metacognition, that are needed to implement a design process successfully **TA.4.7.A** use digital tools to communicate results of an inquiry to inform an intended audience
Science.4.12.B describe the cycling of matter and flow of energy through food webs, including the roles of the Sun, producers, consumers, and decomposers **Career Highlights:** Soil & Plant Scientists, Biologists, Farmworkers & Laborers, Crop, Nursery, & Greenhouse			**ELAR.4.6.G** evaluate details read to determine key ideas **ELAR.4.13.A** generate questions on a topic for formal and informal inquiry **ELAR.4.13.E** demonstrate understanding of information gathered	

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Science Student Expectation	Math Connection	Social Studies Connection	Reading Language Arts Connection	Technology Applications Connection
Science.4.12.C identify and describe past environments based on fossil evidence, including common Texas fossils **Career Highlights:** Geoscientists, Anthropologists & Archeologists, Biologists			**ELAR.4.13.A** use text evidence to support an appropriate response generate questions on a topic for formal and informal inquiry	
Science.4.13.A explore and explain how structures and functions of plants such as waxy leaves and deep roots enable them to survive in their environment **Career Highlights:** Biologists, Zoologists and Wildlife, Geneticists			**ELAR.4.6.G** evaluate details read to determine key ideas **ELAR.4.13.A** generate questions on a topic for formal and informal inquiry **ELAR.4.13.C** identify and gather relevant information from a variety of sources	
Science.4.13.B differentiate between inherited and acquired physical traits of organisms **Career Highlights:** Zoologists and Wildlife Biologists, Biologists, Environmental Science and Protection Technicians			**ELAR.4.6.G** evaluate details read to determine key ideas **ELAR.4.13.A** generate questions on a topic for formal and informal inquiry **ELAR.4.13.C** identify and gather relevant information from a variety of sources	