GUD I Lab: Flight Adaptations—Birds and Planes

Flight Adaptations: Birds and Planes integrates concepts from the physical, life, and earth and space sciences as well as engineering. This last module in this Strand begins by deepening understandings of evolutionary relationships and the evidence to support the development of the tree of life. Here, students focus on bird flight by working with cladograms developed from the fossil record to understand how anatomy changed as the birds of today evolved from the prehistoric dinosaur ancestors. Students consider how the planet is losing bird biodiversity, and who is working to preserve habitats and study ecosystem dynamics (SDG 15). They also compare cladograms developed from anatomical and genome data, giving them insight into the impact of new data on past scientific conclusions. Students then turn to the marvelous adaptation of flight, studying it from two perspectives: 1) bird flight in terms of its evolution and our current understandings of how birds fly, and 2) airplane flight in terms of its underlying physics and the design of human-made “flying machines.” Students observe real birds in flight and document their flight strategies for analysis back in the classroom. They learn how scientists model bird flight strategies, and how engineers engage in biomimicry to create flying robots, drones and planes. Students revisit energy conversions from PE to KE in a system, as this conversion is central to gliding and soaring flight—both natural and anthropogenic designs. They use a PhET simulation to explore the conversation of energy in a skate park, and acceleration due to gravity in the absence of friction (drag). Through studying bird & plane flight, students delve into Newton’s laws of motion, Bernoulli’s principle, and fluid dynamics. In addition, they explore global warming in relation to commercial air travel. Students directly confront issues about commercial air travel and its contribution to climate change (SDG 13). Has COVID-19 changed business travel permanently, and is this good for the environment, for equitable participation in work-related events, and for personal wellbeing? In studying these phenomena, students have the opportunity to understand them in relation to 7 Crosscutting Concepts – patterns, cause and effect; scale, proportion, and quantity; systems and systemic models; energy and matter; structure and function; and stability and change (indicated by color below). This lab provides students with a solid foundation in applying scientific principles to solve an engineering problem, the first of several opportunities for students to combine science and engineering in Integrated Science. It’s a great moment to connect science and engineering practices & purposes. This is the first complete immersion in the entire engineering design process, and students apply scientific principles of flight as they design, build, test, gather new research, employ a real-world engineering decision matrix from the Six Sigma/DMAIC methods, and rebuild balsa-wood models of gliders. Students compare scientific investigation and engineering design, engage in scientific argumentation, direct and inferential evidence, direct vs. indirect relationships, and the iterative design process. As always, they work with a variety of models including 2D & 3D representations, videos, online interactives, and the prototypes they build. After reflecting on their engineering immersion, students learn about a very special glider, the Solar Impulse plane that glided around the world delivering messages of clean energy and reduced carbon emissions (SDG 7 & 17). How will biological and technological flight adapt and evolve in a changing climate?

Matrix of Environmental Principles and Concepts in CA NGSS <u>(Grades 9-12)</u>

Principle I: The continuation and health of individual human lives and of human communities and societies depend on the health of the natural systems that provide essential goods and ecosystem services.

- Human lives, communities, societies, and activities (e.g., agriculture, fisheries, and industry) depend on and benefit from the biodiversity of Earth’s natural systems.

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- The availability and reliability of the ecosystem goods and ecosystem services that natural systems provide humans are directly affected by the size and growth of human populations, and their consumption rates, as well as the operation of human communities.

Principle II: The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies.

- Human population growth and associated anthropogenic changes (e.g., habitat destruction, pollution, climate change, invasive species) result from extracting, harvesting, transporting, and consuming natural resources, and can lead to the disruption of natural systems, thereby influencing the functioning and geographic extent, composition, biological diversity, and viability of ecosystems and threatening the survival of some species.

Principle III: Natural systems proceed through cycles that humans depend upon, benefit from and can alter.

- Human-caused changes to cycles and processes in natural systems can diminish supplies of fresh water and clean air and may also result in global-scale changes such as: desertification, climate change, and decreased availability of arable soil.

Principle IV: The exchange of matter between natural systems and human societies affects the long-term functioning of both.

- The increasing consumption of resources (matter and energy) from growing human populations and associated activities is resulting in global-scale changes to natural systems (e.g., increased amounts of atmospheric carbon dioxide, overfishing, loss of tropical rainforests) which influence the capacity of Earth's natural systems to adjust to human-caused alterations.

- The byproducts of human activities (e.g., pollution, waste products) that result from the expansion and operation of human communities and the use of natural resources, influence the functioning and geographic extent, composition, biological diversity, and viability of ecosystems and can threaten the survival of some species.

Principle V: Decisions affecting resources and natural systems are based on a wide range of considerations and decision-making processes.

- The spectrum of what is considered in making decisions about natural systems and resources, and how those factors influence decisions, should take into account sustaining biodiversity and natural system function, as well as human dependence on the living world for the resources and other benefits provided by biodiversity.

- Global challenges can impact natural systems and resources, as well as social, economic, and political conditions in local communities, therefore engineering design solutions should take into account the full spectrum of these factors when evaluating and engineering design solutions.

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This lab also addresses the following understandings about the *Nature of Science* as described in Appendix H of NGSS:

- Scientific Investigations Use a Variety of Methods (MS&HS)
- Scientific Knowledge is Based on Empirical Evidence (MS&HS)
- Scientific Knowledge is Open to Revision in Light of New Evidence (MS&HS)
- Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena (MS&HS)
- Science is a Way of Knowing (MS & HS)
- Scientific Knowledge Assumes an Order and Consistency in Natural Systems (MS&HS)
- Science as a Human Endeavor (MS&HS)
- Science Addresses Questions About the Natural and Material World (MS&HS)

NRC Framework Disciplinary Core Ideas (DCI) and Crosscutting Concepts Related to the Lab

Crosscutting Concepts Color Key	
■ = Patterns	■ = Energy and matter
■ = Cause and effect	■ = Structure and function
■ = Scale, proportion, and quantity	■ = Stability and change
■ = Systems and systemic models	Brackets [ ] denote additional cross-cutting concepts

NOTE: Where the NGSS Performance Expectations align to both our lab and the Framework DCI, we include the Performance Expectations parenthetically [i.e., (MS-PS1-1)]. This follows the same convention that Achieve follows in their documents.

Physical Sciences	**Life Sciences**	**Earth and Space Sciences**	**Engineering, Technology, and the Application of Science**
Motion and Stability: Forces and Interactions: Forces and Motion (PS2.A)	**From Molecules to Organisms: Structures and Processes: Structure and Function (LS1.A)** In multicellular organisms, the body is a system of multiple interacting	**Earth's Place in the Universe: The History of Planet Earth (ESS1.C)** The geologic time scale interpreted from rock strata	**Engineering Design: Defining and Delimiting Engineering Problems (ETS1.A)**

Physical Sciences	Life Sciences	Earth and Space Sciences	Engineering, Technology, and the Application of Science
For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (MS) The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS) Newton's second law accurately predicts changes in the motion	subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions. (MS) [This lab also connects this DCI to Systems and Systemic Models.] **Ecosystems: Interactions, Energy, and Dynamics (LS2.C)** Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. (HS) **Biological Evolution: Unity and Diversity: Evidence of Common Ancestry and Diversity (LS4.A)** The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life	provides a way to organize Earth's history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale. (MS) **Earth's Systems: Earth Materials and Systems (ESS2.A)** Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (HS) **Earth's Systems: Weather and Climate (ESS2.D)** The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. (HS) [This lab also connects this DCI to Cause and Effect.]	The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. (MS-ETS1-1) Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS) **Engineering Design: Developing Possible Solutions (ETS1.B)** A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (MS-ETS1-4)

Physical Sciences	Life Sciences	Earth and Space Sciences	Engineering, Technology, and the Application of Science
of macroscopic objects. (HS) **Energy: Definitions of Energy (PS3.A)** Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed. (MS-PS3-1, MS-PS3-2) A system of objects may also contain stored (potential) energy, depending on their relative positions. (MS-PS3-1, MS-PS3-2) The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science,	forms throughout the history of life on Earth. (MS) [This lab also connects this DCI to Scale, Proportion, and Quantity.] Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent. (MS-LS4-2) Genetic information, like the fossil record, provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence. (HS) [This lab also connects this DCI to Scale, Proportion, and Quantity.] **Biological Evolution: Unity and Diversity: Natural Selection (LS4.B)**	Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS) [This lab also connects this DCI to Energy and Matter.] Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. (HS) **Earth and Human Activity: Natural Resources (ESS3.A)** Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over	There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2), (MS-ETS1-3) Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ETS1-3) Models of all kinds are important for testing solutions. (MS-ETS1-4) When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS) Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as

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heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. (MS-PS3-1, MS-PS3-2) [This lab also connects this DCI to Systems and Systemic Models.] At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS) **Energy: Conservation of Energy and Energy Transfer (PS3.B)** When the motion energy of an object changes, there is inevitably some other change in energy at the same time. (MS-PS3-1, MS-PS3-2, MS-PS3-5) [This lab also	Natural selection leads to the predominance of certain traits in a population, and the suppression of others. (MS) Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. (HS) [This lab also connects this DCI to Cause and Effect.] The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. (HS) [This lab also connects this DCI to Cause and Effect.] **Biological Evolution: Unity and Diversity: Adaptation (LS4.C)** Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and	human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes. (MS) Resource availability has guided the development of human society. (HS) [This lab also connects this DCI to Scale, Proportion, and Quantity.] All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS) **Earth and Human Activity: Human Impacts on Earth Systems (ESS3.C)** Typically, as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are	running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS) [This lab also connects this DCI to Structure and Function.] **Engineering Design: Optimizing the Design Solution (ETS1.C)** Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. (MS-ETS1-3) The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to

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connects this DCI to Energy and Matter.] Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS) [This lab also connects this DCI to Energy and Matter.] The availability of energy limits what can occur in any system. (HS) [This lab also connects this DCI to Energy and Matter.] Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). (HS) [This lab	reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes. (MS) [This lab also connects this DCI to Stability and Change.] Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. (HS) Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that	engineered otherwise. (MS-ESS3-4) [This lab also connects this DCI to Scale, Proportion, and Quantity.] [This lab also connects this DCI to Stability and Change.] The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. (HS) [This lab also connects this DCI to Cause and Effect.] Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4) **Earth and Human Activity: Global Climate Change (ESS3.D)** Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming).	greater refinement and ultimately to an optimal solution. (MS) Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS)

Physical Sciences	**Life Sciences**	**Earth and Space Sciences**	**Engineering, Technology, and the Application of Science**
also connects this DCI to Energy and Matter.]	have the trait and to a decrease in the proportion of individuals that do not. (HS) [This lab also connects this DCI to Patterns.] [This lab also connects this DCI to Scale, Proportion, and Quantity.] Adaptation also means that the distribution of traits in a population can change when conditions change. (HS) [This lab also connects this DCI to Cause and Effect.] Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. (HS) [This lab also connects this DCI to Stability and Change.] Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost. (HS) [This lab also connects this DCI to Cause and Effect.]	Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities. (MS-ESS3-5) [This lab also connects this DCI to Cause and Effect.] Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS) [This lab also connects this DCI to Scale, Proportion, and Quantity.]	

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Physical Sciences	Life Sciences	Earth and Space Sciences	Engineering, Technology, and the Application of Science
	Biological Evolution: Unity and Diversity: Biodiversity and Humans (LS4.D) Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). (HS) [This lab also connects this DCI to Cause and Effect.]		

NRC Framework Science and Engineering Practices Related to the Lab

Asking questions and defining problems	Developing and using models	Planning and carrying out investigations	Analyzing and interpreting data
Ask questions • that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information. (MS) • to determine relationships between independent and dependent variables and relationships in models. (MS) • to clarify and/or refine a model, an explanation, or an engineering problem. (MS) • that require sufficient and appropriate empirical evidence to answer. (MS) • that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles. (MS) • that challenge the premise(s) of an argument or the interpretation of a data set. (MS) • that arise from examining models or a theory, to clarify and/or seek additional information and relationships. (HS)	Evaluate limitations of a model for a proposed object or tool. (MS) Develop or modify a model—based on evidence—to match what happens if a variable or component of a system is changed. (MS) Use and/or develop a model of simple systems with uncertain and less predictable factors. (MS) Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. (MS) Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism or system in order to select or revise a model that best fits the evidence or design criteria. (HS) Design a test of a model to ascertain its reliability. (HS)	Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions. (MS) Collect data about the performance of a proposed object, tool, process or system under a range of conditions. (MS) Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or design to ensure variables are controlled. (HS) Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts. (HS)	Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success. (MS) Analyze and interpret data to provide evidence for phenomena. (MS) Analyze and interpret data to determine similarities and differences in findings. (MS) Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable

Asking questions and defining problems	**Developing and using models**	**Planning and carrying out investigations**	**Analyzing and interpreting data**
• to clarify and refine a model, an explanation, or an engineering problem. (HS) • that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. (HS) Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. (MS) Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. (HS) Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations. (HS)	Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. (HS) Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. (HS)	Select appropriate tools to collect, record, analyze, and evaluate data. (HS) Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables. (HS)	scientific claims or determine an optimal design solution. (HS) Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. (HS) Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success. (HS)

NRC Framework Science and Engineering Practices Related to the Lab

Using mathematics and computational thinking	**Constructing explanations and designing solutions**	**Engaging in argument from evidence**	**Obtaining, evaluating, and communicating information**
Use mathematical representations to describe and/or support scientific conclusions and design solutions. (MS) Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems. (MS) Use digital tools and/or mathematical concepts and arguments to test and compare proposed solutions to an engineering design problem. (MS)	Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena. (MS) Construct an explanation using models or representations. (MS) Construct a scientific explanation based on valid and reliable evidence obtained from sources (including their own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (MS) Apply scientific ideas, principles and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events. (MS) Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion. (MS) Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system. (MS) Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. (MS)	Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. (MS) Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. (MS) Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. (HS)	Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s). (MS) Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations. (MS) Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in

Using mathematics and computational thinking	**Constructing explanations and designing solutions**	**Engaging in argument from evidence**	**Obtaining, evaluating, and communicating information**
	Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing. (MS) Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. (HS) Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (HS)	Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence. (HS) Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). (HS)	simpler but still accurate terms. (HS) Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. (HS) Communicate scientific and/or technical information (e.g., about a proposed object, tool, process, system) in writing and/or through oral presentations. (HS)

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