ED I Lab: Collecting Qualitative & Quantitative Data on Human Water Consumption

To launch the case study on water resources & access in Mexico and California, students learn how qualitative and quantitative data drive our understanding of a situation, and why both data types are necessary to paint a clear picture. Videos, video poems, story maps and photo essays that capture the global issue of clean water access help make this point. Next, students review a quantitative study from 2011 on human water consumption in Mexico and learn that the 2019 data show that not much has changed over the course of a decade. Inequities in clean water access rear their ugly head as students are prompted to engage in science and engineering practices (SEP) with the analysis and interpretation of quantitative data, including data organizer features, statistics and outliers. Why is Mexico the largest consumer of bottled water in the world? Where does clean, freshwater come from, anyhow? Students take a closer look at the water cycle, aquifers, groundwater basins and watersheds. They study natural and built infrastructure in the state of California, noting the huge demand for 'imported' water and how much energy it takes to transport water through the state. What happens in times of drought? Have overexploited our groundwater resources to the point where seawater is seeping into our well water? This lab combines Disciplinary Core Ideas (DCIs) from all areas: physical, life, earth and space sciences, and engineering design. The core ideas include water flow through ecosystems; pollutant cycling through natural systems such as aquifers, watersheds and freshwater sources; chemical reactions; the composition of natural mixtures; the negative impact that humans have on biodiversity, particularly through the overexploitation of freshwater resources. Students learn about these phenomena in relation to 6 Crosscutting Concepts – patterns; cause and effect; scale, proportion, and quantity; systems and systemic models; energy and matter; and stability and change (indicated by color below). Students learn about contour and topographic maps, tools that are used to study watersheds and groundwater pollution, using maps of watersheds. They apply their new map-reading skills during a environmental forensics mystery in the fictitious town of Riverville. Students determine the culprit of groundwater pollution in the town, making their claim using evidence, and propose solutions to the problem. Throughout the lab, students leverage several scientific reports, as well as interactive diagrams, maps and models. They learn to interpret data from professionally-prepared studies on water quality and access in Mexico and California, and learn cause-effect relationships between groundwater contaminants and those they impact. Students become familiar with safety symbols and the proper use of an electronic balance as they prepare to build and deploy a water treatment device that resembles different aquifer layers. They craft their device using plastic water bottles and explore the plastic waste generated by these bottles, not only in Mexico but around the world. Sustainable solutions are needed! This entire lab gives students the opportunity to work on a variety of science and engineering practices, particularly analyzing and interpreting data; constructing explanations; engaging in argumentation; evaluating and proposing solutions; and obtaining, evaluating, and communicating information.

A note about the **UN Sustainable Development Goals (SDGs):** This lab, and most subsequent labs, connect directly to one or more SDGs. This lab highlights SDG #6, *Clean Water and Sanitation*, but also: SDG #1: *No Poverty*; SDG #3, *Good Health and Well-being*; SDG #12, *Responsible Production and Consumption*; and SDG #15, *Life on Land*. Students will be introduced to the SDGs later, in the final lab of ED I. Students are introduced to the SDGs briefly in their **Introduction**, but they will take a retrospective look at the SDGs in the labs they have completed *in the last lab of ED I*. Since everything is still quite new for students, we felt that this approach would allow students to ease into all of the novelty rather than feel overwhelmed. Beginning in GUD I, students address the SDGs in a given lab as they progress.

Matrix of Environmental Principles and Concepts in CA NGSS (Grades 9-12)

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.
- The biodiversity of natural systems influences the quality, quantity, and reliability of the ecosystem goods and ecosystem services that human lives, communities, societies, and activities depend on.
- 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 social systems (e.g., laws, economics, and politics) and practices (e.g., methods used to extract, transport, and resource consumption) can alter natural systems processes and cycles, thereby influencing the carrying capacities of ecosystems and their geographic extent, composition, biological diversity, health, viability, and functioning.
- 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 practices, including the methods used to extract, harvest, transport and consume natural resources alter the cycles and processes that operate within natural systems, directly and indirectly influencing the quality, quantity, and reliability of ecosystem goods and ecosystem services available to support human lives, communities, and societies.
- Human activities can alter Earth's major cycles and processes influencing the geographic extent, composition, biological diversity, health, viability, and functioning of natural systems.
- 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.

- The scope, scale, and duration of human activities that consume natural resources and produce byproducts, influence the capacity of natural systems to recover from human-caused alterations and directly influence both the long-term viability of associated natural systems and the sustainability of human societies.

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.

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 (HS)
- Science is a Way of Knowing (MS&HS)
- Scientific Knowledge Assumes an Order and Consistency in Natural Systems (MS&HS)
- Science is 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**
Matter and Its Interactions: Structure and Properties of Matter (PS1.A) Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS) Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. (MS)	**Ecosystems: Interactions, Energy, and Dynamics: Interdependent Relationships in Ecosystems (LS2.A)** Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. (MS) **Ecosystems: Interactions, Energy, and Dynamics: Ecosystem Dynamics, Functioning, and Resilience (LS2.C)** Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any	**Earth's Systems: Earth's Materials and Systems (ESS2.A)** All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms. (MS) [This lab also connects this DCI to Systems and Systemic Models.] The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future. (MS) [This lab also connects this DCI to Systems and Systemic Models.]	**Engineering Design: Defining and Delimiting Engineering Problems (ETS1.A)** Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1) [This lab also connects this DCI to

Physical Sciences	Life Sciences	Earth and Space Sciences	Engineering, Technology, and the Application of Science
Matter and Its Interactions: Chemical Reactions (PS1.B) Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS) **Energy: Conservation of Energy and Energy Transfer (PS3.B)** 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.]	physical or biological component of an ecosystem can lead to shifts in all its populations. (MS-LS2-4) [This lab also connects this DCI to Cause and Effect.] 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) [This lab also connects this DCI to Cause and Effect.] [This lab also connects this DCI to Patterns.] **Biological Evolution: Unity and Diversity: Biodiversity and Humans (LS4.D)** Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling. (MS-LS2-4) [This lab also connects this DCI to Cause and Effect.]	**Earth's Systems: The Role of Water in Earth's Surface Processes (ESS2.C)** Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land. (MS-ESS2-4) Global movements of water and its changes in form are propelled by sunlight and gravity. (MS) Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations. (MS) The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. (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	Patterns.] [This lab also connects this DCI to Structure and Function.] **Engineering Design: Developing Possible Solutions (ETS1.B)** Models of all kinds are important for testing solutions (MS) [This lab also connects this DCI to Systems and Systemic Models.]

Physical Sciences	Life Sciences	Earth and Space Sciences	Engineering, Technology, and the Application of Science
	Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (HS)	resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes. (MS-ESS3-1) Resource availability has guided the development of human society. (HS) 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) [This lab also connects this DCI to Cause and Effect.] **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 engineered otherwise. (MS-ESS3-3) (MS-ESS3-4) [This lab also connects this DCI to Systems and Systemic Models.] 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.]	

Physical Sciences	Life Sciences	Earth and Space Sciences	Engineering, Technology, and the Application of Science
		Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS) **Earth and Human Activity: Global Climate Change (ESS3.D)** Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities. (HS)	

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 identify and/or clarify evidence and/or the premise(s) of an argument. (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, 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) • 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)	Develop and/or use a model to predict and/or describe phenomena. (MS) Develop a model to describe unobservable mechanisms. (MS) Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. (MS)	Evaluate the accuracy of various methods for collecting data. (MS) Select appropriate tools to collect, record, analyze, and evaluate data. (HS)	Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships. (MS) Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships. (MS) Analyze and interpret data to provide evidence for phenomena. (MS) Analyze and interpret data to determine similarities and differences in findings. (MS) Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. (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 digital tools (e.g., computers) to analyze very large data sets for patterns and trends. (MS) Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems. (MS)	Construct an explanation using models or representations. (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 ideas or principles to design, construct, and/or test a design of an object, tool, process or system. (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)	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) Integrate qualitative and/or quantitative scientific and/or technical information in written text with that contained in media and visual displays to clarify claims and findings. (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 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)