Environmental Dynamics II Lab: AIR All Around

This first lab of both *Environmental Dynamics* and Level II challenges students to take the next step in their STEM journey. As outlined in What's New in Level II, students encounter more authentic STEM databases, primary source journal articles, and disciplinary integration from Disciplinary Core Ideas (DCIs) in physical, life, earth and space sciences and engineering. *Environmental Dynamics II* is grounded in the work of the Stockholm Resilience Centre, and this lab centers on three of their nine planetary boundaries: Stratospheric ozone depletion, Atmospheric aerosol loading, and Novel entities (including chemical pollutants). Students explore stratosphere ozone through a problem set on related atmospheric chemistry that explore the results of an international scientific assessment of ozone depletion. Students also learn about NASA's visualizations of the ozone hole, as well as the dedicated work of scientists exploring the impacts of CFCs, that led to the now-successful Montreal Protocol. Students chronicle the winding and non-linear STEM process that these scientists experienced. Next, students arrive in the troposphere, where ambient air quality is of pressing importance. Students learn about criteria air pollutants, their chemistry, and their anthropogenic sources. Using 3 data sets of global air quality data, students create their own statistical analyses and data visualizations to support a claim about air quality correlations for a single country. They practice identifying the type of feedback that will support writing improvements, engaging in authentic scientific peer review with classmates. As they progress through this data dive, they learn about the policy and legal framework that helps shape country policies—and data reporting conventions—alongside multi-disciplinary STEM research. Students then switch gears to learn about another atmospheric force that impacts the biosphere: air pressure. Boyle's and Charles' Laws come into focus, as students continue to compare direct and inverse relationships. Students revisit genetic adaptations and compare them to the acclimatization process experienced by mountain climbers and scuba divers. Zooming out to put the biosphere in perspective, students compare altitude, latitude and world ecosystems, noting conditions that are similar as one moves to higher elevations and higher latitudes. The wide variety of DCIs covered in this lab support the integration of all 7 Crosscutting Concepts – patterns; cause and effect; scale, proportion, and quantity; systems and systemic models; energy; structure and function; and stability and change (indicated by color below). Students learn about these ideas and concepts through engaging in a variety of scientific practices. They have multiple opportunities to derive and analyze information regarding biodiversity and human impact issues from technical reports and interactive media. Students conduct hands-on protocols to model the impact of colder and warmer "environments" on an air sample, and model the relationship between the pressure and the volume of a gas at constant temperature.

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 (HS)
- Scientific Knowledge is Based on Empirical Evidence (HS)
- Scientific Knowledge is Open to Revision in Light of New Evidence (HS)
- Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena (HS)
- Science As a Way of Knowing (HS)
- Scientific Knowledge Assumes an Order and Consistency in Natural Systems (HS)
- Science As a Human Endeavor (HS)
- Science Addresses Questions About the Natural and Material World (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., (HS-PS1-1)]. This follows the same convention that Achieve follows in their documents.

In Level II, All DCIs and Practices are aligned only to HS level, even if parts of the lab correlate to MS.

Physical Sciences	Life Sciences	Earth and Space Sciences	Engineering Design
Matter and Its Interactions: Structure and Properties of Matter (PS1.A) Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS-PS1-1) The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-2)	**Structures and Processes: Structure and Function (LS1.A)** Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. (HS-LS1-3) **Structures and Processes: Organization for Matter and Energy Flow in Organisms (LS1.C)** As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in	**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-ESS2-2) [This lab also connects this DCI to Cause and Effect.] The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation,	**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

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The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3) [This lab also connects this DCI to Energy and Matter.] [This lab also connects this DCI to Stability and Change.] **Matter and Its Interactions: Chemical Reactions (PS1.B)** The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS) [This lab also connects this DCI to Energy and Matter.] [This lab also connects this DCI to Stability and Change.] **Motion and Stability: Forces and Interactions: Types of Interactions (PS2.B)** Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (HS-PS1-1) [This lab also connects this DCI to Structure and Function.]	different ways to form different products. (HS) **Matter and Energy in Organisms and Ecosystems: Cycles of Matter and Energy Transfer in Ecosystems (LS2.B)** Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. (HS) Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. (HS-LS2-5) **Ecosystems: Interactions, Energy, and Dynamics: Ecosystem Dynamics, Functioning, and Resilience (LS2.C)** A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. (HS-LS2-5) [This lab also connects this DCI to Energy and Matter.] [This lab also connects this DCI to Cause and Effect.] Moreover, anthropogenic changes (induced	and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. (HS-ESS2-2; HS-ESS2-4) [This lab also connects this DCI to Systems and Systemic Models.] **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-ESS2-2; HS-ESS2-4) Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS-ESS2-6) [This lab also connects this DCI to Scale, Proportion and Quantity.] 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	local communities. (HS) **Engineering Design: Defining and Delimiting Engineering Problems (ETS1.B)** 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)

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Energy: Definitions of Energy (PS3.A) At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS) [This lab also connects this DCI to Systems and Systemic Models.] **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) 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) **Waves and Their Applications in Technologies for Information Transfer: Electromagnetic Radiation (PS4.B)** When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into	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-LS2-5) [This lab also connects this DCI to Energy and Matter.] [This lab also connects this DCI to Cause and Effect.] **Heredity: Variation of Traits (LS3.B)** Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. (HS-LS4-1; HS-LS4-4) **Biological Evolution: Evidence of Common Ancestry and Diversity (LS4.A)** 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-LS4-1; HS-LS4-4) **Biological Evolution: Evidence of Common Ancestry and Diversity: Natural Selection (LS4.B)** Natural selection occurs only if	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-ESS2-2; HS-ESS2-4) [This lab also connects this DCI to Cause and Effect.] [This lab also connects this DCI to Scale, Proportion and Quantity.] **Earth's Systems: Biogeology (ESS2.E)** The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it. (HS-ESS3-1) [This lab also connects this DCI to Systems and Systemic Models.] **Earth and Human Activity: Natural Resources (ESS3.A)** Resource availability has guided the development of human society. (HS-ESS3-1) [This lab also connects this DCI to Stability and Change.] [This lab also connects this DCI to Scale, Proportion and Quantity.] **Earth and Human Activity: Human Impacts on Earth Systems (ESS3.C)**	

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thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. (HS) [This lab also connects this DCI to Stability and Change.]	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-LS4-1; HS-LS4-4) The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. (HS-LS4-1; HS-LS4-4) **Biological Evolution: Unity and Diversity: Adaptation (LS4.C)** 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 have the trait and to a decrease in the proportion of individuals that do not. (HS-LS4-1; HS-LS4-4) **Biological Evolution: Unity and Diversity: Biodiversity and Humans (LS4.D)** 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,	The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. (HS-ESS3-1) [This lab also connects this DCI to Stability and Change.] [This lab also connects this DCI to Scale, Proportion and Quantity.] Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4) [This lab also connects this DCI to Systems and Systemic Models.] [This lab also connects this DCI to Scale, Proportion and Quantity.] **Earth and Human Activity: Global Climate Change (ESS3.D)** 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-ESS3-5) [This lab also connects this DCI to Systems and Systemic Models.] [This lab also connects this DCI Patterns.] [This lab also connects this DCI to Scale,	

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	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-LS2-7) [This lab also connects this DCI to Stability and Change.]	Proportion and Quantity.] 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-ESS3-6) [This lab also connects this DCI Patterns.] [This lab also connects this DCI to Stability and Change.] [This lab also connects this DCI to Scale, Proportion and Quantity.]	

NRC Framework Science and Engineering Practices Related to the Lab

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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, or unexpected results, to clarify and/or seek additional information. • that arise from examining models or a theory, to clarify and/or seek additional information and relationships. • to determine relationships, including quantitative relationships, between independent and dependent variables. • to clarify and refine a model, an explanation, or an engineering problem. Evaluate a question to determine if it is testable and relevant. Ask questions 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. 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.	Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationship between systems or between components of a system Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. 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. Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.	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 effects and evaluate the investigation's design to ensure variables are controlled. Select appropriate tools to collect, record, analyze, and evaluate data.	Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.

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Using mathematics and computational thinking	**Constructing explanations and designing solutions**	**Engaging in argument from evidence**	**Obtaining, evaluating, and communicating information**
Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.).	Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources including students' own investigations, models, theories, simulations, peer review) 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. Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which	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. Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence, challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining additional information required to resolve contradictions. Make and defend a claim based on evidence about the natural world or the effectiveness of a design	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. 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. Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of

Using mathematics and computational thinking	**Constructing explanations and designing solutions**	**Engaging in argument from evidence**	**Obtaining, evaluating, and communicating information**
	the reasoning and data support the explanation or conclusion.	solution that reflects scientific knowledge and student-generated evidence.	development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, and mathematically).