Harvard Forest Schoolyard Ecology Connections to
Next Generation Science Standards

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The best way that Harvard Forest Schoolyard Ecology assists teachers in meeting the NGSS standards is by providing a way for your students to engage in authentic ***science practices.***

Practice 1 Asking Questions and Defining Problems

Students at any grade level should be able to ask questions of each other about the texts they read, the features of the phenomena they observe, and the conclusions they draw from their models or scientific investigations. (NRC Framework 2012, p. 56)

Grades 3-5	***Grades 6-8***	***Grades 9-12***
Asking questions and defining problems in 3–5 builds on K–2 experiences and progresses to specifying qualitative relationships *• Ask questions about what would happen if a variable is changed. • Identify scientific (testable) and non-scientific (nontestable) questions.* *• Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.*	*Asking questions and defining problems in 6–8 builds on K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.* *• Ask questions o that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information. o to identify and/or clarify evidence and/or the premise(s) of an argument. or to determine relationships between independent and dependent variables and relationships in models. o to clarify and/or refine a model, an explanation, or an engineering problem. or that require sufficient and appropriate empirical evidence to answer. o 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. or that challenge the premise(s) of an argument or the interpretation of a data set.*	*Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.* *• Ask questions o that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. o that arise from examining models or a theory, to clarify and/or seek additional information and relationships. o to determine relationships, including quantitative relationships, between independent and dependent variables. o to clarify and refine a model, an explanation,* *• Evaluate a question to determine if it is testable and relevant.* *• Ask questions that can be investigated within the scope of the 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.*

Practice 3 Planning and Carrying Out Investigations *Students should have opportunities to plan and carry out several different kinds of investigations during their K-12 years. At all levels, they should engage in investigations that range from those structured by the teacher—in order to expose an issue or question that they would be unlikely to explore on their own (e.g., measuring specific properties of materials)— to those that emerge from students' own questions. (NRC Framework, 2012, p. 61)*

Grades 3-5	**Grades 6-8**	**Grades 9-12**
Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K– 2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions. *• Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.* *• Evaluate appropriate methods and/or tools for collecting data.* *• Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.* *• Make predictions about what would happen if a variable changes.*	*Planning and carrying out investigations in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions.* *• Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.* *• Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.* *• Evaluate the accuracy of various methods for collecting data.* *• Collect data to produce data to serve as the basis for evidence to answer scientific questions or test*	*Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.* *• Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence …supporting explanations for phenomena. Consider possible confounding variables or effects and evaluate the investigation's design…* *• Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.* *• Plan and conduct an investigation … in a safe and ethical manner including considerations of environmental, social, and personal impacts.* *• Select appropriate tools to collect, record, analyze, and evaluate data.*

Practice 4 Analyzing and Interpreting Data

Once collected, data must be presented in a form that can reveal any patterns and relationships and that allows results to be communicated to others. Because raw data as such have little meaning, a major practice of scientists is to organize and interpret data through tabulating, graphing, or statistical analysis. Such analysis can bring out the meaning of data—and their relevance—so that they may be used as evidence. (NRC Framework, 2012, p. 61-62)

Grades 3-5	***Grades 6-8***	***Grades 9-12***
Analyzing data in 3–5 builds on K–2 experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. When possible and feasible, digital tools should be used. *• Represent data in tables and/or various graphical displays (bar graphs, pictographs and/or pie charts) to reveal patterns that indicate relationships.* *• Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation.* *• Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.*	*Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.* *• Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.* *• Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.* *• Distinguish between causal and correlational relationships in data.* *• Analyze and interpret data to provide evidence for phenomena.* *• Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible.* *• Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials).* *• Analyze and interpret data to determine similarities and differences in findings.*	*Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.* *• Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims.* *• 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 of a proposed process or system.*

Practice 5 Using Mathematics and Computational Thinking

Although there are differences in how mathematics and computational thinking are applied in science…, mathematics often brings these two fields together by enabling engineers to apply the mathematical form of scientific theories and by enabling scientists to use powerful information technologies designed by engineers. Both kinds of professionals can thereby accomplish investigations and analyses and build complex models, which might otherwise be out of the question. (NRC Framework, 2012, p. 65)

Grades 3-5	***Grades 6-8***	***Grades 9-12***
Mathematical and computational thinking in 3–5 builds on K–2 experiences and progresses to extending quantitative measurements to a variety of physical properties and using computation and mathematics to analyze data and compare alternative design solutions. *• Organize simple data sets to reveal patterns that suggest relationships.* *• Describe, measure, estimate, and/or graph quantities (e.g., area, volume, weight, time) to address scientific questions and problems.*	*Mathematical and computational thinking in 6–8 builds on K–5 experiences and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.* *• Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends.* *• Use mathematical representations to describe and/or support scientific conclusions.* *• Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific questions and problems.*	*Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. .* *• Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.* *• Apply techniques of algebra and functions to represent and solve scientific problems.* *• 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.).*

Practice 6 Constructing Explanations and Designing Solutions

The goal of science is to construct explanations for the causes of phenomena. Students are expected to construct their own explanations, as well as apply standard explanations they learn about from their teachers or reading. The Framework states the following about explanation: "The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories."(NRC Framework, 2012, p. 52)

Grades 3-5	***Grades 6-8***	***Grades 9-12***
Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems. *• Construct an explanation of observed relationships (e.g., the distribution of plants in the back yard).* *• Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation* *• Identify the evidence that supports particular points in an explanation.*	*Constructing explanations and designing solutions in 6–8 builds on K– 5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.* *• Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.* *• Construct an explanation using models or representations.* *• Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' 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.* *• Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for realworld phenomena, examples, or events.* *• Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.*	*Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.* *• 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 the reasoning and data support the explanation or conclusion*

Practice 8 Obtaining, Evaluating, and Communicating Information

Any education in science and engineering needs to develop students' ability to read and produce domain-specific text. As such, every science or engineering lesson is in part a language lesson, particularly reading and producing the genres of texts that are intrinsic to science and engineering. (NRC Framework, 2012, p. 76)

Grades 3-5	***Grades 6-8***	***Grades 9-12***
Obtaining, evaluating, and communicating information in 3–5 builds on K–2 experiences and progresses to evaluating the merit and accuracy of ideas and methods. • *Read and comprehend grade appropriate complex texts and/or other reliable media to summarize and obtain scientific and technical ideas and describe how they are supported by evidence.* • *Compare and/or combine across complex texts and/or other reliable media to support the engagement in other scientific …practices.* • *Combine information in written text with that contained in corresponding tables, diagrams, and/or charts to support the engagement in other scientific …practices.* • *Obtain and combine information from books and/or other reliable media to explain phenomena* • *Communicate scientific and/or technical information orally and/or in written formats, including various forms of media as well as tables, diagrams, and charts*	*Obtaining, evaluating, and communicating information in 6–8 builds on K–5 experiences and progresses to evaluating the merit and validity of ideas and methods.* • *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).* • *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.* • *Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy… of each publication and methods used, and describe how they are supported or not supported by evidence.* • *Evaluate data, hypotheses, and/or conclusions in scientific and technical texts in light of competing information or accounts.* • *Communicate scientific and/or technical information in writing and/or through oral presentations.*	*Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs.* • *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* • *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 in multiple formats (i.e., orally, graphically,*

NGSS Disciplinary Core Idea Progression Core Concepts that relate most closely to Harvard Forest Schoolyard Ecology Projects

Disciplinary Core Idea	***Grades 3-5***	***Grades 6-8***	***Grades 9-12***
ESS2.E Biogeology	*Living things can affect the physical characteristics of their environment.*	*[Content found in LS4.A and LS4.D]*	*The biosphere and Earth's other systems have many interconnections that cause a continual coevolution of Earth's surface and life on it*
ESS3.A Natural resources	*Energy and fuels humans use are derived from natural sources and their use affects the environment. Some resources are renewable over time, others are not.*	*Humans depend on Earth's land, ocean, atmosphere, and biosphere for different resources, many of which are limited or not renewable. Resources are distributed unevenly around the planet as a result of past geologic processes.*	*Resource availability has guided the development of human society and use of natural resources has associated costs, risks, and benefits.*
ESS3.C Human impacts on Earth systems	*Societal activities have had major effects on the land, ocean, atmosphere, and even outer space. Societal activities can also help protect Earth's resources and environments.*	*Human activities have altered the biosphere, sometimes damaging it, although changes to environments can have different impacts for different living things. Activities and technologies can be engineered to reduce people's impacts on Earth.*	*Sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources, including the development of technologies*
ESS3.D Global climate change	*N/A*	*Human activities affect global warming. Decisions to reduce the impact of global warming depend on understanding climate science, engineering capabilities, and social dynamics.*	*Global climate models used to predict changes continue to be improved, although discoveries about the global climate system are ongoing and continually needed.*
LS1.B Growth and development	*Reproduction is essential to every kind of organism.*	*Animals engage in behaviors that increase the odds of*	*N/A*

of organisms	*Organisms have unique and diverse life cycles.*	*reproduction. An organism's growth is affected by both genetic and environmental factors.*	
LS1.C Organization for matter and energy flow in organisms	*Food provides animals with the materials and energy they need for body repair, growth, warmth, and motion. Plants acquire material for growth chiefly from air, water, and process matter and obtain energy from sunlight, which is used to maintain conditions necessary for survival.*	*Plants use the energy from light to make sugars through photosynthesis. Within individual organisms, food is broken down through a series of chemical reactions that rearrange molecules and release energy.*	*The hydrocarbon backbones of sugars produced through photosynthesis are used to make amino acids and other molecules that can be assembled into proteins or DNA. Through cellular respiration, matter and energy flow through different organizational levels of an organism as elements are recombined to form different products and transfer energy.*
LS2.A Interdependent relationships in ecosystems	*The food of almost any animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants, while decomposers restore some materials back to the soil*	*Organisms and populations are dependent on their environmental interactions both with other living things and with nonliving factors, any of which can limit their growth. Competitive, predatory, and mutually beneficial interactions vary across ecosystems but the patterns are shared.*	*Ecosystems have carrying capacities resulting from biotic and abiotic factors. The fundamental tension between resource availability and organism populations affects the abundance of species in any given ecosystem.*
LS2.B Cycles of matter and energy	*Matter cycles between the air and soil and among*	*The atoms that make up the organisms in an ecosystem are cycled*	*Photosynthesis and cellular respiration provide most of the energy for life processes. Only*

transfer in ecosystems	*organisms as they live and die.*	*repeatedly between the living and nonliving parts of the ecosystem. Food webs model how matter and energy are transferred among producers, consumers, and decomposers as the three groups interact within an ecosystem*	*a fraction of matter consumed at the lower level of a food web is transferred up, resulting in fewer organisms at higher levels. At each link in an ecosystem elements are combined in different ways and matter and energy are conserved. Photosynthesis and cellular respiration are key components of the global carbon cycle*
LS2.C Ecosystem dynamics, functioning, and resilience	*When the environment changes some organisms survive and reproduce, some move to new locations, some move into the transformed environment, and some die*	*Ecosystem characteristics vary over time. Disruptions to any part of an ecosystem can lead to shifts in all of its populations. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.*	*If a biological or physical disturbance to an ecosystem occurs, including one induced by human activity, the ecosystem may return to its more or less original state or become a very different ecosystem, depending on the complex set of interactions within the ecosystem.*
LS4.C Adaptation	*Particular organisms can only survive in particular environments.*	*Species can change over time in response to changes in environmental conditions through adaptation by natural selection acting over generations. Traits that support successful survival and reproduction in the new environment become more common.*	*Evolution results primarily from genetic variation of individuals in a species, competition for resources, and proliferation of organisms better able to survive and reproduce. Adaptation means that the distribution of traits in a population, as well as species expansion, emergence or extinction, can change when conditions change.*
LS4.D Biodiversity and humans	*Populations of organisms live in a variety of habitats. Change in those habitats affects the organisms living there.*	*Changes in biodiversity can influence humans' resources and ecosystem services they rely on.*	*Biodiversity is increased by formation of new species and reduced by extinction. Humans depend on biodiversity but also have adverse impacts on it. Sustaining biodiversity is essential to supporting life on Earth.*