**Appendix A. Overview of *Looking Backwards, Looking Forward* Student Activity**

*Looking Backwards, Looking Forward* is an activity designed to engage students in the scientific practices of asking questions, analyzing and interpreting data, engaging in argument from evidence and obtaining, evaluating and communicating information that are the foundation of the Next Generation Science Standards.

In this activity, students will use a model to simulate the collection of pollen proxy data. Colored beads in bags of soil are used to represent mimic authentic sediment sampled from the Anacostia watershed spanning ~12,500 years before present. Students sort through the bags of soil, separating out the different taxa of ‘pollen’ (beads) and using a key to identify the type of taxon based on bead color.

After sorting and identifying the simulated pollen data, students will analyze and interpret the data to determine what different taxa were likely present at different time periods. They will use information provided on climate requirements of the different taxa to infer past climatic condition and construct scientific explanations about what the climate in this region was like as different times over the past 12,500 years.

Finally, students will examine and interpret a graph that plots temperature anomalies (in degrees Celsius) over the past ~20,000 years. Through discussions, videos and readings, students will explore how current rates of climate change compare to past rates of climate change and how the current very rapid rates of climate change, caused by increases in the amount of CO2 being released into the atmosphere by humans, will affect existing species and ecosystems.

Throughout this activity, students will learn disciplinary core ideas from life science and earth space science while making connections to cross-cutting concepts such as patterns, cause and effect, scale, proportion and quantity, and stability and change.

**Learning Goals:**

The goal of this lesson is two-fold. First, students will use a complex data set they create to develop a scientific argument (a claim, supported by evidence and reasoning) of what a region’s climate was like and how it has changed over the past 12,500 years. Second, it challenges students to consider how the rapid changes occurring in our current climate contrast to these earlier changes and how rates of change did/can impact ecosystems. These lessons are aligned with the Next Generation Science Standards as well as College and Career Ready Standards.

To achieve this overarching goal, students will:

* Use a model of a sediment core containing fossilized pollen to collect pollen proxy data
* Analyze and interpret data derived from an authentic dataset
* Construct a scientific argument to explain how climate in a region has changed over 12,500 years
* Explore the rate of change in today’s climate and compare it to the rate reflected in the pollen data set
* Explore how current rapid rate of climate change is affecting organisms and ecosystems

**Appendix B: Professional Learning Workshop Agendas**

**Day 1: March 5, 2016**

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| 9:00 – 9:30 | Welcome and pre-program survey |
| 9:30 – 10:00 | *Looking Backwards, Looking Forward* Engage |
| 10:00 – 10:30 | *Looking Backwards, Looking Forward* Jigsaw |
| 10:30 – 10:40 | Break |
| 10:40 – 11:15 | *Looking Backwards, Looking Forward* Data Collection in SciTech Lab |
| 11:15 - 12:00 | Intro to Argumentation and CER rubric |
| 12:00 - 12:30 | Lunch, networking and silent ‘auction’ |
| 12:30 - 1:30 | CER and Argumentation |
| 1:30 - 2:00 | Rate of Climate Change |
| 2:00 – 2:15 | Break |
| 2:15 – 3:15 | *Ask an Expert!* |
| 3:15 – 3:30 | Connections to NGSS and Three-Dimensional Teaching |
| 3:30 - 3:45 | Wrap-up and Exit Ticket |
| 3:45 - 4:00 | Material Distribution |

**Day 2: May 7, 2016**

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| 9:00 – 9:15 | Welcome and Stipend Paperwork |
| 9:15 – 10:30 | *Looking Backwards, Looking Forward* Debrief and Feedback |
| 10:30 – 10:45 | Break |
| 10:45 – 11:45 | Connections to NGSS |
| 11:45 – 12:30 | Lunch |
| 12:30 - 1:30 | Student Artifacts |
| 1:30 - 2:00 | Wrap-Up, Survey and Exit ticket |

**Appendix C: Example argument used in professional learning workshop**

Adapted from materials provided by Science Learning Design, Engineering and Robotics at Georgia Tech (“Making a Strong Argument,” n.d.)

Our pulse rates changed. Our group completed five trials where one student measured their pulse rate before and after exercising and did jumping jacks for 30 seconds. The first trial pulse rate before exercise was 62 beats a minute and after exercise increased to 94 beats a minute. We learned in science class that when you exercise, your muscles burn stored energy and need more oxygen. Your blood brings the oxygen to your muscles. The heart rate in our experiment increased after jumping jacks, and therefore the harder you exercise, the faster your heart beats to deliver the oxygen.

**Appendix D: Connections to Next Generation Science Standards**

### Middle School NGSS

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| **Dimension** | **Name and NGSS code/citation** | **Specific Connections to Classroom Activity** |
| Practices | Planning and Carrying Out investigations  - Collect data to produce data to serve as the basis for evidence to answer scientific questions or to test design solutions under a range of conditions. | Students will collect data on frequency of fossilized pollen found in sediment cores and use this as evidence to make and support a claim about Earth’s past climate. |
|  | Analyzing and Interpreting Data  - Analyze and interpret data to provide evidence for phenomena.  - Analyze and interpret data to determine similarities and differences in findings. | Students will analyze and interpret patterns of pollen frequency to make a claim, supported by evidence and reasoning, about what a region’s past climate was like.  Students will compare patterns of fossilized pollen from different time periods (up to 12,500 ybp), noting similarities and differences in claims about inferred past climates. |
|  | Engaging in Argument from Evidence  - Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts.  - Respectfully provide and receive critiques about one’s explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.  - 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 | Students will compare and critique each other’s scientific arguments about Earth’s past climates.  Students will critique their peer’s scientific arguments on Earth’s past climates.  Students will present oral arguments to their peers to support their claims and will challenge their peer’s claims that lack adequate evidence and/or appropriate reasoning. |
|  | Obtaining, Evaluating, and Communicating Information  - 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. | Students will use scientific ideas and reasoning presented in the “Plant Taxa Characteristics Table s” to analyze and interpret the pollen frequency data they have collected in order to construct scientific arguments. |
| Disciplinary Core Ideas | ESS1.C: The History of Planet Earth  - The geologic time scale interpreted from rock strata 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-ESS1-4) | Students will understand that Carbon-14 dating was used to provide a timescale for the pollen fossils found in the sediment core. |
|  | ESS2.A: Earth’s Materials and Systems  - 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-ESS2-2) | Students will explore timescales and fluctuating climatic conditions and understand that scientists are able to learn about climatic conditions from thousands and millions of years ago by utilizing fossil records. |
|  | ESS3.C: Human Impacts on Earth Systems  - Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth’s environments can have different impacts (negative and positive) for different living things. (MS-ESS3-3)  - 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) | Students will explore how the rapid rate of climate change, due to human activity, might affect biomes and ecosystems. |
|  | ESS3.D: Global Climate Change  - 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). 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) | Students will discuss how recent increases in Earth’s temperature are due to humans releasing unprecedented amounts of greenhouse gases. |
|  | LS1.B: Growth and Development of Organisms  - Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction. (MS-LS1-4)  - Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (secondary to MS-LS3-2) | Students will learn that pollen is the male gamete in seed-bearing plants and that pollen can be dispersed via other animals as well as by the wind. |
|  | LS2.C: Ecosystem Dynamics, Functioning, and Resilience  - Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (MS-LS2-4)  - Biodiversity describes the variety of species found in Earth’s terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem’s biodiversity is often used as a measure of its health. (MS-LS2-5) | Students will explore how biomes, ecosystems and individual species are affected by, and respond to, changes in climate. |
|  | LS4.D: Biodiversity and Humans  - 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. (secondary to MS-LS2-5) | Students will explore possible effects of a changing climate on present-day ecosystems and resources. |
|  | LS4.A: Evidence of Common Ancestry and Diversity  - 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 forms. (MS –LS-4-1) | Students will use information from a fossil record (a sediment core containing fossilized pollen modeled using beads to present frequency of pollen grains) to construct a scientific argument that describes Earth’s past climatic conditions. |
| Crosscutting Concepts | Patterns  - Students recognize that macroscopic patterns are related to the nature of microscopic and atomic-level structure. They identify patterns in rates of change and other numerical relationships that provide information about natural and human designed systems. They use patterns to identify cause and effect relationships, and use graphs and charts to identify patterns in data. | Students will examine patterns in data showing frequency of different taxa of pollen collected to construct scientific arguments of past climatic events. |
|  | Cause and Effect  - Students classify relationships as causal or correlational, and recognize that correlation does not necessarily imply causation. They use cause and effect relationships to predict phenomena in natural or designed systems. They also understand that phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. | Students will explore how climate can affect species composition of ecosystems and they will use patterns of frequency of fossilized pollen to infer past climatic conditions. |
|  | Stability and change  - Students explain stability and change in natural or designed systems by examining changes over time, and considering forces at different scales, including the atomic scale. Students learn changes in one part of a system might cause large changes in another part, systems in dynamic equilibrium are stable due to a balance of feedback mechanisms, and stability might be disturbed by either sudden events or gradual changes that accumulate over time. | Students will explore climate changes (both current historical) and how those changes can affect ecosystems. |

### High School NGSS

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| **Dimension** | **Name and NGSS code/citation** | **Specific Connections to Classroom Activity** |
| Practices | Analyzing and Interpreting Data  - Analyze data using tools, technologies, and/or models (e.g., computational mathematical) in order to make valid and reliable scientific claims). | Students will analyze and interpret patterns of pollen frequency to make a claim, supported by evidence and reasoning, about what a region’s past climate was like.  Students will compare patterns of fossilized pollen from different time periods (up to 12,500 ybp), noting similarities and differences in claims about inferred past climates. |
|  | Engaging in Argument from Evidence  - 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. | Students will compare and critique each other’s scientific arguments about Earth’s past climates.  Students will critique their peer’s scientific arguments on Earth’s past climates.  Students will present oral arguments to peers to support their claims and will challenge peer’s claims that lack adequate evidence and/or appropriate reasoning. |
|  | Obtaining, Evaluating, and Communicating Information  - Compare, integrate and evaluate scientific and/or technical information presented in different formats (e.g., visually, quantitatively) as well as in order to address a scientific question. | Students will use scientific ideas and reasoning presented in the “Plant Taxa Characteristics Tables” to analyze and interpret the pollen frequency data they have collected in order to construct scientific arguments. |
| Disciplinary Core Ideas | ESS1.C: The History of Planet Earth  - Radioactive decay lifetimes and isotopic content in rocks provide a way of dating rock formations and thereby fixing the scale of geological time. (HS-ESS1-5) | Students will understand that Carbon-14 dating was used to provide a timescale for pollen fossils found in the sediment core. |
|  | ESS3.C: Human Impacts on Earth Systems  - The sustainability of human societies and the biodiversity that support them require responsible management of natural resources. (HS-ESS3-3) | Students will explore how the rapid rate of climate change, due to human activity, might affect biomes and ecosystems. |
|  | ESS3.D: Global Climate Change  - Global climate models are often used to understand the process of climate change because these changes are complex and can occur solely over Earth’s history. Though the magnitudes of humans’ impacts are greater than they have ever been, so too are human’s abilities to model, predict, and mange current and future impacts. (HS-ESS3-5) | Students will discuss how recent increases in Earth’s temperature are due to humans releasing unprecedented amounts of greenhouse gases and how understanding past climates help scientists build models that predict future climate conditions. |
|  | LS2.C: Ecosystem Dynamics, Functioning, and Resilience  - A complex set of interactions within an ecosystem can keep its number and types of organisms relatively constant over long periods of time under stable conditions. (HS-LS2-2, HS-LS2-7)  -- 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-LS2-7) | Students will explore how biomes, ecosystems and individual species are affected by, and respond to, changes in climate. |
|  | LS4.D: Biodiversity and Humans  - 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. These problems have the potential to cause a major wave of biological extinctions—as many species or populations of a given species, unable to survive in changed environments, die out—and the effects may be harmful to humans and other living things. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. (HS-LS4-6, HS-LS2-7) | Students will explore possible effects of a changing climate on present-day ecosystems and resources. |
| Crosscutting Concepts | Patterns  - Students observe patterns in systems at different scales and cite patterns as empirical evidence for causality in supporting their explanations of phenomena. They recognize classifications or explanations used at one scale may not be useful or need revision using a different scale; thus requiring improved investigations and experiments. They use mathematical representations to identify certain patterns. | Students will examine patterns in data showing frequency of different taxa of pollen collected to construct scientific arguments of past climatic events. |
|  | Cause and Effect  - Students understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They also propose causal relationships by examining what is known about smaller scale mechanisms within the system. They recognize changes in systems may have various causes that may not have equal effects. | Students will explore how climate can affect species composition of ecosystems and they will use patterns of frequency of fossilized pollen to infer past climatic conditions. |
|  | Scale, proportion and Quantity  - Students understand the significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. They recognize patterns observable at one scale may not be observable or exist at other scales, and some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. Students use orders of magnitude to understand how a model at one scale relates to a model at another scale. | Students will explore that changes in ecosystems happen over such vast amounts of time and cannot always be observed directly by humans and must be examined using proxy (indirect) data. |
|  | Stability and change  - Students understand much of science deals with constructing explanations of how things change and how they remain stable. They quantify and model changes in systems over very short or very long periods of time. | Students will explore paleoclimatologists construct explanations about Earth’s past climates by using proxy data that spans thousands of years. |

### Connecting to the Nature of Science

#### Middle School NOS Connections

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| **Nature of Science Category** | **NOS Learning Outcomes** | **How Nature of Science ideas are explicitly addressed in Classroom Activity** |
| Scientific Investigations Use a Variety of Methods | - Science investigations use a variety of methods and tools to make measurements and observations. | Students will explore idea that not all scientific data come from controlled experiments in reflective question: *“Does all science require controlled experiments? Provide specific examples from this activity to support your answer.”* |
| Scientific Knowledge is Based on Empirical Evidence | - Science knowledge is based upon logical and conceptual connections between evidence and explanations. | Students will develop scientific arguments about past climatic conditions based on data and will explicitly reflect on the role of data in science when answer the reflective question *“Why are data important in science?”* |
| Scientific Knowledge Assumes an Order and Consistency in Natural Systems | - Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. | Students will explore this idea in reflective question *“An important aspect of science is identifying and explaining patterns in nature. Explain below why this is important for scientists to do, using an example from your climate investigation.”* |

#### High School NOS connections

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| **Nature of Science Category** | **NOS Learning Outcomes** | **How Nature of Science ideas are explicitly addressed in Classroom Activity** |
| Scientific Investigations Use a Variety of Methods | - Science investigations use diverse methods and do not always use the same set of procedures to obtain data. | Students will explore the idea that not all scientific data comes from controlled experiments in the reflective question *“Does all science require controlled experiments? Provide specific examples from this activity to support your answer.”* |
| Scientific Knowledge is Based on Empirical Evidence | - Science knowledge is based on empirical evidence.  - Scientific arguments are strengthened by multiple lines of evidence supporting a single explanation. | Students will develop scientific arguments about past climatic conditions based on data and will explicitly reflect on the role of data in science when answer the reflective question *“Why are data important in science?”*  - Students will review and critique scientific arguments. |