Chapter 1

Field Investigations and the Next Generation Science Standards

"Students...need experiences that help them recognize that the laboratory is not the sole domain for legitimate scientific inquiry and that, for many scientists (e.g., earth scientists, ethologists, ecologists), the "laboratory" is the natural world where experiments are conducted and data are collected in the field." (Schweingruber, 2012)

What are field investigations?

Field investigations of the environment involve the systematic collection of data for the purposes of scientific understanding. They are designed to answer a question through the collection of evidence and the communication of results; they contribute to scientific knowledge by describing natural systems, noting differences in habitats, and identifying environmental trends and issues.

Why conduct field investigations?

Field investigations help students become systems thinkers, provide opportunities to engage in science and engineering practices and understand that science does not only happen in a laboratory or classroom. Outdoor experiences in natural settings increase students' problem solving abilities and motivation to learn in social studies, science, language arts and math. Outdoor experiences also provide students with place-based connections and engage students in relevant learning experiences. Outdoor, placed-based learning, as an instructional strategy, encompasses a range of techniques and approaches that build on students' interests and backgrounds so as to engage them more meaningfully and support them in sustained learning. These strategies have been shown to promote educational equity in learning science and engineering.

The Three Dimensions of the Next Generation Science Standards (NGSS) (Next Generation Science Standards: For States, By States, 2013)

The Framework for K-12 Science Education and the Next Generation Science Standards are built on three integrated dimensions:

- Science and Engineering Practices
- Crosscutting Concepts
- Disciplinary Core Ideas

Field investigations can provide opportunities for students to engage in all three of the dimensions of the Next Generation Science Standards. The specific components of each of the three dimensions are outlined in the table below.

Science & Engineering Practices	Crosscutting Concepts	Disciplinary Core Ideas
1. Ask questions (for science) and define problems (for engineering) 2. Develop and use models 3. Plan and carry out investigations 4. Analyze and interpret data 5. Use mathematics and computational thinking 6. Construct explanations (for science) and design solutions (for engineering) 7. Engage in argument from evidence 8. Obtain, evaluate, and communicate information	1. Patterns 2. Cause and effect 3. Scale, proportion, and quantity 4. Systems and system models 5. Energy and matter 6. Structure and function 7. Stability and change	**Physical sciences** • Matter • Force & Motion • Energy • Waves **Life sciences** • Structure & Processes • Ecosystems • Heredity • Evolution **Earth and space sciences** • Earth in the Universe • Earth Systems • Earth & Human Activity **Engineering, technology and applications of science**

Crosscutting Concepts

When planning and conducting field investigations, students and scientists grapple with the difficulties of working in a natural system while at the same time developing an understanding of its complexities and subsystems. In order to understand the system, students need to utilize the Crosscutting Concepts in concert with the associated Disciplinary Core Ideas.

The questions below provide some examples of how students and teachers might use the Crosscutting Concepts to make sense of their outdoor learning experiences.

Patterns: What patterns do we notice in the system? What patterns do we notice in our data?

Cause and Effect: What might be causing ________ to happen?

Scale, Proportion, and Quantity: How many ________ are in this area? Are some organisms larger in one area than another? What parts of the system might be very small or unseen?

Systems and Systems Models: What are the important parts of the system? How do the parts work together?

Energy and Matter: Where are energy and matter flowing through this system?

Structure and Function: How does the structure of ______ relate to its function?

Stability and Change: What parts of the system are changing over time? What parts seem to stay the same?

Science and Engineering Practices

The Next Generation Science Standards encourage instruction that focuses students on solving problems and explaining phenomena - activities which characterize the pursuits of scientists and engineers. In field investigations, students pose a question then plan and conduct an investigation to answer that question. Students use evidence to support explanations and build models, as well as to pose new questions about the environment. Students learn that the scientific method is not a simple linear process and, most importantly, experience the difficulty of answering essential questions such as:

- What defines my environment?
- What are all the parts and interrelationships in this ecosystem?
- What is a healthy environment?
- What is humans' relationship to the environment?
- How has human behavior influenced our environment?
- How can our community sustain our environment?
- What is my role in the use and preservation of environmental resources?

Science beyond the laboratory or classroom

Field investigations help students become informed citizen scientists and engineers, contributing knowledge to their community's understanding of natural resources in order to make issues of concern visible and share differing points of view about the preservation and use of those resources. The Next Generation Science Framework highlights how "all science learning can be understood as a cultural accomplishment." Research shows that a cultural perspective can transform learning experiences to make them more engaging and meaningful for learners. Informal learning environments can be particularly good at engaging youth from non-dominant communities in science learning and identification.

How are field investigations different from controlled laboratory experiments?

Classroom science often overemphasizes experimental investigation in which students actively manipulate variables and control conditions. Experiments begin with a hypothesis regarding links between variables in a system followed by identifying those variables of interest and designing a "fair test" where the variables are manipulated, controlled and measured to gather evidence to construct an explanation or solve a problem.

Investigations in the natural world where it is difficult to manipulate variables and maintain "control" and "experimental" groups scientists look for descriptive, comparative, or correlative trends in events. Many field investigations begin with gathering baseline data followed by measurements intentionally taken in various locations (e.g. urban and rural, or where some natural phenomenon has created different plot conditions) because of a prediction that differences will occur.

Are all field investigations the same?

No. For conceptual clarity, we have identified three types of field investigations—descriptive, comparative, and correlative.

Descriptive field investigations:	**Comparative field investigations:**	**Correlative field investigations:**
Involve describing and/or quantifying parts of a natural system.	Involve collecting data on different populations/organisms, or under different conditions (e.g. times of year, locations), to make a comparison.	Involve measuring or observing two variables and searching for a relationship.

Each type of field investigation is guided by different types of investigative questions. Descriptive studies can lead to comparative studies, which can lead to correlative studies. The three types of field investigations are often used in combination to study the natural world.

A model for field investigation

The table below outlines the differences and similarities between the three types of field investigations and relates these to the essential features of inquiry. See Windschitl, M., Dvornich, K., Ryken, A. E., Tudor, M., & Koehler, G. (2007) A comparative model of field investigations: Aligning School Science Inquiry with the Practices of Contemporary Science, School Science and Mathematics 1 (107), 367-390 for a complete description of the field investigation model.

THREE TYPES OF FIELD INVESTIGATIONS			
Essential Questions	What defines my environment? What is a healthy environment? What is humans' relationship to the environment? How can our community sustain our environment? What is my role in the preservation and use of environmental resources?		
	Descriptive	**Comparative**	**Correlative**
Formulate Investigative Question	How many? How frequently? When did it happen?	Is there a difference between groups, conditions, times, or locations? Make a prediction or hypothesis about differences.	Is there a relationship between two variables? Make a hypothesis about the relationship.
Identify Setting within a System	Identify geographic scale of investigation (e.g., riparian corridor or Cedar River Watershed) Identify time frame of the investigation (e.g., season, hour, day, month, year)		
Identify Variables of Interest	Choose measurable or observable variables	Choose a measured variable in at least two different (manipulated variable) locations, times, organisms, or populations	Choose two variables to be measured together and tested for a relationship

<table>
<tr><th></th><th>Descriptive</th><th>Comparative</th><th>Correlative</th></tr>
<tr><td rowspan="2">Carry out Investigations</td><td colspan="3">Multiple measurements over time or location in order to improve system representation (model)
Individual measurement is repeated if necessary to improve data accuracy
Record and organize data into table(s) or other forms</td></tr>
<tr><td></td><td colspan="2">Describe how sampling, measurement, observations were consistent for the two or more locations, times or organisms (controlled variables) and was random and representative of the site.</td></tr>
<tr><td>Analyze and Interpret Data</td><td colspan="3">Means, medians, ranges, percentages, estimations calculated when appropriate.
Organize results in graphic and/or written forms and maps using statistics where appropriate
What patterns do we notice in the data?
Might there be any cause and effect relationships here?</td></tr>
<tr><td></td><td colspan="2">Typical representations of the data to build descriptive and comparative models
• Charts
• Line Plots
• Bar Graphs
• Maps</td><td>Typical representations of the data to demonstrate correlations upon which models are developed
• Scatter plots
• r-values</td></tr>
<tr><td rowspan="2">Construct an Evidence-Based Explanation or Argument</td><td colspan="3">Makes a claim that answers the investigative question.
Use evidence from observations collected to support the claim.</td></tr>
<tr><td colspan="3">Does the claim answer the question?
Does the evidence support the claim?
Does the reasoning connect the evidence to the claim?
Does the reasoning contain a science principle?</td></tr>
<tr><td>Discussion</td><td colspan="3">What questions do I have about the data we collected?
What questions do I have about the way we gathered the data?
What other data or information might we need to collect or find?
How does this data help us to understand the entire system?
Did we identify any problems that might need to be solved?</td></tr>
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Documenting the Field Investigation Science Practice

Identify the Phenomenon to Be Investigated

The phenomenon (something puzzling that students are trying to explain) and purpose of the investigation is described. The essential question and investigation question are identified.

Essential Question is the big picture question that cannot be answered with one investigation.

Investigation Question is the researchable question that can be answered with qualitative or quantitative observations or measurements.

Make a Prediction (Initial Claim)

Predictions are not typically made for descriptive studies. For comparative studies, students predict what will happen to the responding (measured) variable when one of the changes occurs. For correlative studies predict the relationship. Secondary students should also give a reason for their prediction.

Decide on Materials

The materials needed to perform the investigation are listed.

Plan the Field Investigation

The investigation plan includes:

- Logical steps to do the investigation; steps written clearly so someone else could follow procedure.
- What variables are under study? What is changed (manipulated/independent)? What is measured (responding/dependent)?
- How, when and/or where will observations/measurements be taken? How will samples or measurements be repeated?
- How is sampling/measurement method consistent (controlled variables) or systematic? Secondary students should describe how sampling is random and representative of the site.

Carry out the Investigation (Collect the Data)

Data/observations/measurements are recorded systematically on a data collection sheet. Location, date, time of day and a description of study site (including weather) are recorded.

Analyze and Interpret Data

Organize Data

Results are organized into categories in tables, charts, graphs, maps, and/or other written forms making appropriate calculations (e.g. total growth, distances, total number observed).

Populations are estimated; means, modes, medians, t-values and r-values are calculated; graphs, tables, or maps are generated.

Identify Relationships

Patterns and trends in the data are observed and described.

Interpret Data

Relationships are identified in the data and how these patterns identified in the data provide evidence for a conclusion or claim is described.

Construct an Argument/Explanation

An argument/explanation is constructed that answers the original question being investigated based on the evidence collected and analyzed. This argument/explanation includes:

- **A claim**

  A one sentence answer to the question.
- **Evidence**

  Supports the claim above with sufficient and appropriate evidence collected in the investigation.
- **Supportive reasoning (justification)**

  Connects the evidence to the claim using justification and scientific principles.

Extend the Investigation

Investigations are extended to allow for students and the class to make sense of the investigation in a broader context than just the specific field investigation that was conducted. The following are ideas:

- Compare data to other similar systems models.
- Identify factors in the field that may have affected the outcomes of the investigation.
- Describe how the procedures might have been more systematic.
- Compare scientific arguments by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail. Provide and receive critiques on arguments.
- Provide new questions about the system or model.
- Recommend future actions and explain why.
- Add to the model of the current system under study.