Project-Based Learning Model

Relevant Learning for the 21st Century

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A Project of the Association of Fish and Wildlife Agencies' North American Conservation Education Strategy

Developed by the Pacific Education Institute

Funded by a Multistate Grant of the Sport Fish and Wildlife Restoration Program

December 2011

PEI PACIFIC EDUCATION INSTITUTE

ASSOCIATION of FISH & WILDLIFE AGENCIES

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Developed By
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Margaret Tudor, Ph.D.
Lynne Ferguson
Co-Executive Directors

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RPV4.26.17AF

Acknowledgments

The following organizations provided support for
Project-based Learning Model, Relevant Learning for the 21st Century:

Sport Fish and Wildlife Restoration Program

Association of Fish and Wildlife Agencies

(AFWA) North American Conservation Education Strategy

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Jeff Rawlinson, Nebraska Game and Parks Commission

Warren Gartner, Indiana Division of Fish and Wildlife

Thomas Baumeister, Montana Fish, Wildlife and Parks

Project-based Learning Model, Relevant Learning for the 21st Century was made possible by the Pacific Education Institute and University of Washington's Dr. Catherine Taylor facilitating multiple stakeholders to develop Environmental Education Frameworks that describe the expected student performance through projects. The integration of systems thinking was facilitated by the valuable insight of Nalani Linder. We would like to give a special thanks to all of the Washington State educators (formal and non-formal) and students who provided us the opportunity to refine this model through their hands on involvement with projects to improve their local environments.

Visionaries at the Washington Department of Fish and Wildlife, including Michael O'Malley, Watchable Wildlife Program Manager and Rocky Beach, Wildlife Diversity Program Manager.

The Board of Directors of the Pacific Education Institute, consisting of leaders in the formal education sector and natural resource agencies and organizations, recognized the need to provide guidelines for field studies. Their support was essential to making the ***Project-based Learning Model*** a reality.

The Pacific Education Institute and the Association of Fish and Wildlife Agencies are indebted to the national environmental education organizations of Project WILD, Project Learning Tree and Project WET for paving the way for K-12 environmental science education. The AFWA/PEI environmental science process materials would not be possible without the leadership of these organizations to bring meaningful learning experiences to students.

Margaret Tudor, Ph.D.
Executive Director, Pacific Education Institute

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Introduction

The Pacific Education Institute's ***Project-Based Learning Model*** engages students in relevant learning that positively impacts their local communities and ecosystems. Teachers or mentors facilitate, rather than direct, students as they explore a system, ask questions, look at problems within that system, determine solutions, plan and ultimately implement a project.

Through the Pacific Education Institute's ***Project-Based Learning Model***, students take ownership for their learning, structure and organize an action project, and inform others about an environmental issue. In other words, students become empowered and educated citizens of the 21st century.

The projects themselves can be pre-determined by an educator or can be completely determined by the students. For example, a teacher or mentor may have the funding and/or desire to work with students to design and install a rain garden on the school campus. Or the educator may know he or she would like to conduct a project on the school campus, but does not know what project would have the greatest impact on the students and the environment. Either way, the teacher and students collaborate as they work through the ***Project-Based Learning Model*** process. The result is a student-guided service learning project that involves students in the technological design process while building and enhancing content knowledge, problem solving abilities, systems thinking and communication skills.

PEI's ***Project Based Learning Model*** aligns with the Framework for K-12 Science Education that emphasizes scientific and engineering practices using cross-cutting concepts (e.g. patterns, stability and change, systems) to apply science to disciplinary core ideas. In the Project-based Learning Model, the disciplinary core ideas of focus are the macro-worlds of Life Sciences and Earth Sciences. In addition, the model provides a framework that facilitates curriculum integration, environment-oriented action projects, and opportunities for students to showcase their achievements. It encourages systems thinking skills—such as seeing the big picture, looking for interdependencies within a system, and considering both short- and long-term consequences of actions—all of which are critical for effectively dealing with the complex and interconnected issues in our environment today (Environmental Education Framework, 2001).

In order to explain some of the steps, we used the example of constructing a rain garden. When you see references to rain gardens, use as a guide to inform your project.

Science and Engineering Practices

The Project-Based Learning Model applies science and engineering practices to address a problem of a human need or want. The Framework for K-12 Science Education describes the three human enterprises of science, technology and engineering in the following way:

> **Technology** is any modification of the natural world made to fulfill human needs or desires. (NAS, 2011)
>
> **Engineering** is a systematic and often iterative approach to designing objects, processes, and systems to meet human needs and wants. (NAS, 2011)
>
> An **application of science** is any use of scientific knowledge for a specific purpose, whether to do more science: to design a product, process, or medical treatment, to develop a new technology; or to predict the impacts of human actions. (NAS, 2011)

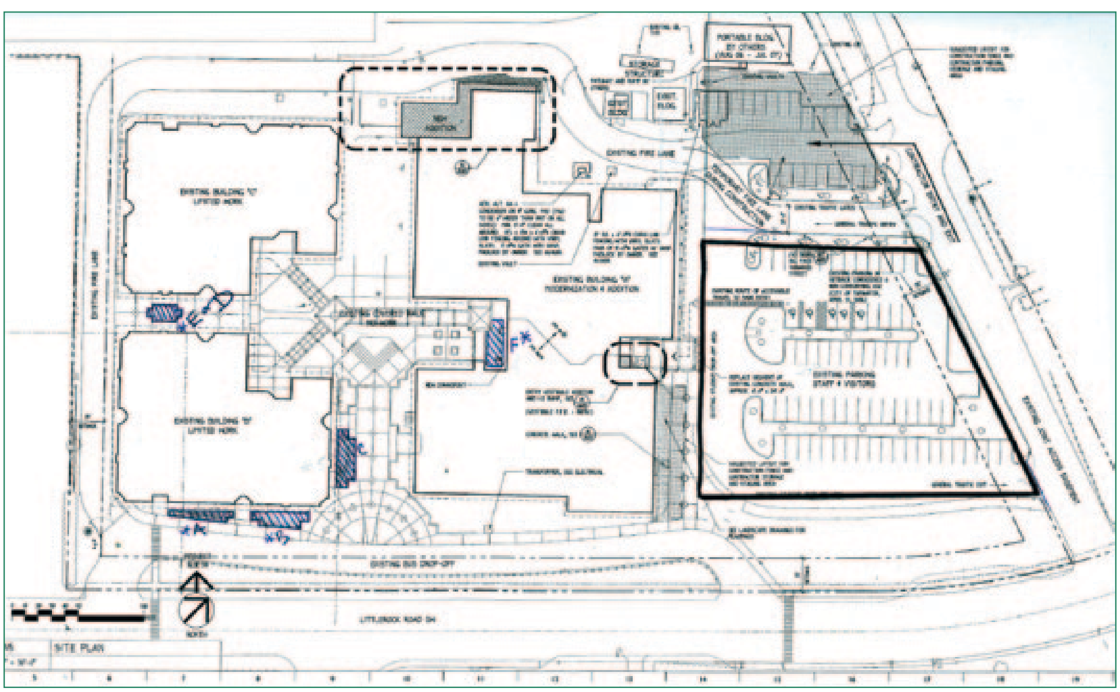
Students engaging in the science and engineering design process need to follow a set of engineering practices that engineers use as they design and build systems. The National Academy of Sciences uses the term "practices" instead of skills to emphasize that students need not only skill but also knowledge that is specific to each practice. Students need to be engaged directly in these scientific and engineering practices in order to fully understand how to apply scientific knowledge to problems through engineering solutions. The science and engineering practices essential for K-12 science and engineering (see Appendix A for full description) are: (NAS, 2011)

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics, information and computer technology, and computational thinking.
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence.
8. Obtaining, evaluating, and communicating information.

The Project-based Learning Model provides a scaffold or structure for students to engage in each of these practices by taking the steps to develop and implement a project.

This structure provides students a process to follow to design investigations, helping them learn how to observe, design, determine variables to measure, plus record and evaluate data using appropriate tools and instruments. For example, in middle school, students can apply their scientific knowledge of ecology concepts to solve problems related to a school garden through engineering design (NRC, 2011 3017). In high school students can undertake more complex engineering design projects that address major local, national and global issues (NRC, 2011).

The Frameworks (NRC, 2011) expect students to write accounts of their work, using journals to record observations, thoughts, ideas and models. In addition, students in scientific investigation and applying science through engineering are encouraged to create diagrams, sketches and models and represent data and observations with plots and tables, plus written text, to communicate detailed plans in the journals. Students need access to complex texts, such as technical reports and scientific and technological/engineering literature on the Internet. Students developing engineering projects need to develop systems thinking and systems models, that support critical steps in developing, sharing, testing and refining design ideas. Teachers can use the "Sustainable Tomorrow: A Teachers' Guidebook for Applying Systems Thinking to Environmental Education Curricula for Grades 9-12" to develop the habits of systems thinking and model, through graphic representations of behavior over time, input and output flow, and causal loops showing negative and positive feedback, using mathematical thinking.



The Pacific Education Institute's Project-Based Learning Model Overview

Through PEI's Project-Based Learning Model, students:

<table>
<tr><th></th><th>Role of Teachers</th></tr>
<tr><td>Step 1: Describe the Ecosystem
Describe the biological, geological, and physical properties of the local ecosystem and how it interacts with and connects to the larger system.</td><td rowspan="4">Curriculum Integration</td></tr>
<tr><td>Step 2: Define the Problem
Identify a local problem that involves the system.</td></tr>
<tr><td>Step 3: Research the Problem
Gain deeper insight into the problem while establishing criteria for measuring a solution's effectiveness in addressing the problem.</td></tr>
<tr><td>Step 4: Understand Stakeholders
Identify the perspectives, interests and positions of the major groups and individuals that may influence or be impacted by the problem and/or potential solutions.</td></tr>
<tr><td>Step 5: Determine Possible Solutions
Determine and compare solutions in relation to possible impacts, stakeholder perspectives, limitations and feasibility.</td><td rowspan="3">Action Projects & Stewardship</td></tr>
<tr><td>Step 6: Develop a Plan
Work collaboratively to develop a plan to solve the problem - identify required resources and steps needed for implementation, and reflect on the potential outcomes of the solution.</td></tr>
<tr><td>Step 7: Implement the Plan
Carry out the plan in collaboration with others, and keep records of the process and results.</td></tr>
<tr><td>Step 8: Summarize, Evaluate and Reflect
Evaluate, reflect upon and communicate the plan's results, including intended and unintended consequences, and its effectiveness based on the criteria for success.</td><td>Showcase Project</td></tr>
</table>

Project Journals

As each student works through his/her project, whether he/she is working with the class, a small group or individually, the *Journal* serves as a means of project organization. Any materials or resources used, as well as any hard-copy document produced, should be placed in this journal. Providing project guidelines, including the journal layout, helps students learn valuable organization skills, while ensuring all components of a project are completed.

Upon completion, the journal then becomes a student portfolio that communicates the progression and depth of a project, as well as a means for showcasing student work.

Recommended Layout

Work with students to obtain a 3-ring binder and create a **title page** for the project journal (including project name, student name, school, mentor name and affiliation, and dates).

The contents of the journal can be organized into sections (dividers) using the steps of the Project Based Learning Model:

Ecosystem Description
The Problem*
Stakeholders
Possible Solutions
Project Plan
Plan Implementation
Evaluation/Reflection
Bibliography

*** *The Problem* section combines *Step 2: Define the Problem* and *Step 3: Research the Problem.***

Documentation of Sources: The Annotated Bibliography

In the professional world, documentation of resources for any published work is a necessity. Ensuring that students record information in their own words has always been a challenge for teachers. With the advent of the Internet, the copy and paste means of gathering information is all too common. Frequently, students fail to note the source, much less check to see if the source is valid and reliable.

Combined with teacher guidance and classroom discussions about the assessment of sources, the compilation of an annotated bibliography ensures that each student not only determines general statistics about sources, such as the author and date, but also the quality and value of information presented. Looking closer at documents and webpages used for research helps students develop heightened awareness about the types, quality and potential bias of sources and the information presented within those sources.

For younger students, a simple bibliography can be required, particularly if the teacher provides the websites and/or written materials for students to utilize during research and project preparations. However, a discussion about how to analyze and determine the quality of sources is recommended.

Student Page:

Annotated Bibliography

Collect and record information for ALL of the sources you access throughout your project. This includes web pages, magazines, books, newspapers and even people you interview. The Annotated Bibliography will be placed at the back of your Project Journal.

Follow the criteria below:

- Format may be in either **APA** (American Psychological Association) or **MLA** (Modern Language Association) format.
- Include at least **10 sources**.
- Cite sources from a variety of formats. Include at least **three** different types.
  - Books
  - Magazines/scientific journals
  - Movies/documentaries
  - On-line/electronic sources*
  - Pamphlets or brochures
  - Personal interviews
  - Newspaper articles or editorials
- **Annotation:**

  Following each citation (author, title, etc.) add a short paragraph (between 50 and 100 words) that:
  - Summarizes the information found within the source.
  - Describes the usefulness of the source to your project. (If it *is* useful, describe *how it is useful*. If *not,* explain *why* it is *not useful*.)

* Be sure you accurately determine the author of a webpage or web-based document. The web-hosting company is not necessarily the author.

Step 1: Describe the Ecosystem

> **Practices in Science and Engineering**
>
> 2. Develop and Using Models
>
> See Appendix A

Whether a project is *pre-determined* or *to-be-determined* (as discussed in the *Introduction*), students must understand the ecosystem in which they will be working. Through the Ecosystem Description, students visit and explore a site to make observations about the components and interactions taking place within that system. During this process, students not only gain insight into the potential problems at that site, but also develop a frame of reference which is further developed as students conduct additional research on the Internet, in a library or in the classroom.

Before exploring a site, teachers can provide specific background information (and even mention the pre-determined project, if desired) or simply show the students a digital map of the site, utilizing Geographic Information Systems (GIS) resources such as Google Maps, Google Earth or even ArcGIS, so that they develop a general understanding of the site and the surrounding area.*

Additionally, a teacher or mentor may wish to revise the ***Ecosystem Description Notes*** document prior to the Ecosystem Description field experience to ensure students make more specific observations related to a particular topic or issue. For example, if a teacher has pre-determined that she would like her students to design and install a rain garden (the project), the student observations would include a focus on finding areas of standing water, saturated ground and large non-pervious surfaces.

While visiting a site with their teacher or a guest expert, students are given the opportunity to explore the area and thoroughly describe their observations and predictions related to changes over time (*Step 1 Student Page (A): Ecosystem Description Notes*) either independently or with a small team. Additionally, they are encouraged to ask questions** related to their observations (*Step 1 Student Page (B): Ecosystem Questions*). To further enhance student observations in the field, each student also creates a simple technical drawing that communicates both his/her observations of the components and interactions he/she observes within that ecosystem (*Step 1 Student Page (C): Sketch and Label Your Ecosystem*).

After the site visit, students conduct further research about the components of the Ecosystem, possibly adding more complex components such as the Nutrient Cycles and/or Energy Transfers and Transformations, if desired. Additionally, students are encouraged to find the answers to some of their questions, if possible.

The final product of the *Ecosystem Description* can be a collection of field notes and drawings, a formal write up describing the ecosystem (components and interactions), a *Changes over Time* graph and/or a detailed technical drawing that depicts the components and interactions in that system.

* See ***Landscape Investigation Guide,*** (PEI 2011)

**For more information related to types of questions and how to guide students to ask quality questions, see Appendix B or Field Investigation Guide – Section 2, Parts 1 and 2 (PEI, 2007).

> What is causing the squishy, muddy area next to the basketball court?
>
> When is there standing water or muddy ground next to the court?
>
> Where do the birds go if they can't make nests at our school?
>
> How can we stop the wearing down of the grass?

Note: During Ecosystem Description research, teachers may need to remind students to record all the sources they use for research on their Annotated Bibliographies.

Student Page:
Step 1 INSTRUCTIONS

Step 1: Ecosystem Description Instructions

1. Write down your observations on the ***Step 1 Student Page (A): Ecosystem Description Notes*** page.
    - Use all of your senses to observe and describe the vegetation (plants), animals, water, human impacts and topography/geology at your site.
    - Be sure to include any observations about how these features affect each other and/or your site, or how your site affects the features.
2. Write down the questions you think of while making observations on the ***Step 1 Student Page (B): Ecosystem Questions.***
3. Continue making observations and asking questions until **all of the components of the Ecosystem Description** have been described.
4. Then, find a place to sit.
5. Draw and label a picture on the ***Step 1 Student Page (C): Sketch and Label your Ecosystem*** page that shows the features, or components, of the site, as well as any connections or interactions between the features.
6. Then think about what the area will look like in the future. Below your sketch, be sure to:
    - Choose one feature you have observed, such as the trees, birds or buildings.
    - Write about what might change and what might stay the same.

    (For example, a student is observing an area that has a playground with old equipment and a number of puddles. The student decides to predict how the puddles might change over time. The student writes that in 1 year, the site will have 4 more puddles. In 10 years, the puddles will have merged into a single, shallow puddle. And in 100 years, the single puddle will grow wider and deeper - becoming more like a pond.)

7. When you are done, follow your teacher's instructions.

Student Page (A) EXAMPLE:

Step 1. Ecosystem Description Notes

Name Ollie Observer **Location and Date:** PGS Elementary, 4/11/2010

1. Vegetation – what types, quantity, invasive species, etc.

   A Douglas fir tree has caused cracks in the sidewalk along side Mr. M's class because one of its roots is trying to grow through it. One scotch broom growing by the back fence. 3 Cherry trees, 4 Douglas fir trees

2. Animals – species, status, diversity, etc.

   Swallow nests up under the edges of the roof that keep being knocked down. Birds spotted: 2 Stellar's jays, 4 juncos, 6 crows, and 3 swallows. Lots of ants. Dog walking on front sidewalk.

3. Water – sources, locations, currents, etc.

   A big area next to the basketball court is "mushy" and muddy with large puddles. 10 puddles on playground

4. Human impacts – settlements/activities and technologies being used/behaviors

   The students have created a trail between Portable A and B where no grass can grow. The basketball court is in the middle of a big grassy area. The school has roads on all 4 sides and a big parking lot on one side.

5. Topography/Geology – elevation, formation history, features, etc.

   The school is not in the mountains, but is on a slight hill with some low spots on the playground and near the basketball court. The school dirt is clay with some gravel.

6. How does this ecosystem interact with/connect to <u>your local environment?</u>

   The water that comes off of our sidewalks and parking lots goes into drains at the edge of the school property. This water goes into a creek and to the Puget Sound

7. Do you notice any situations that should be dealt with in the ecosystem or things that are affecting the ecosystem? Be specific.

   The squishy ground and standing water next to the basketball court might need to be dealt with. There are no places for birds to put their nests. Also, there isn't much habitat for animals. I'd love to see a garden somewhere. Kids seem to be wearing down a path in the grass (so there's only dirt) next to the C building

Step 1. Student Page (A):
Ecosystem Description Notes

Name **Location and Date:**

1. Vegetation – what types, quantity, invasive species, etc.

2. Animals – species, status, diversity, etc.

3. Water – sources, locations, currents, etc.

4. Human impacts – settlements/activities and technologies being used/behaviors

5. Topography/Geology – elevation, formation history, features, etc.

6. How does this ecosystem interact with/connect to <u>your local environment?</u>

7. Do you notice any situations that should be dealt with in the ecosystem or things that are affecting the ecosystem? Be specific.

Step 1. Student Page (B):

Ecosystem Questions

As you make observations and research the components of the ecosystem, **<u>record any questions you may have in the space below</u>.**

Think about:

- sources (Who___? or What___? or Where___?)
- causes (How___?)
- effects or impacts (What would happen if___?)
- reasons (Why___?)
- timing (When___?)
- numbers (How many___?)
- or any other question you think about.

Step 1. Student Page (C):

Sketch and Label Your Ecosystem

Once you have explored the site, find a place to sit, draw and label an image that shows the components and interactions you observed in that ecosystem.

Name:

Location and Date

Choose one feature of this site (such as the trees, birds, buildings, etc.). Predict what it might be like in the future. Be sure to think about what might stay the same and what might change.

In 1 year:

In 10 years:

In 100 years:

Step 2: Define the Problem

Practices in Science and Engineering

1. Asking Questions & Defining Problems

See Appendix A

The term *problem* has a variety of definitions and connotations. Most likely, when students hear the word *problem*, they assume something is wrong. However, in the case of Project-Based Learning, the ***problem*** is simply a challenge that can be solved through the design process, a series of steps used to design and solve a problem. In other words, the *problem* is the **purpose or reason for a project**.

Prior to Step 2, teachers or mentors must first work with students to *define* the term *problem* in the context of Project-Based Learning. (For the activity: ***What is a Problem?*** see Appendix C.) This process clarifies student misconceptions and provides students with examples to build from as they begin to determine their potential projects.

Once the term *problem* has been defined, the teacher or mentor works with students through Step 2 to either:

1. Clearly define the problem for a pre-selected project. (See Version 1)

or

2. Determine and define a problem by looking through the *Ecosystem Description* observations and conducting further research or investigations as needed. (See Version 2)

Examples of Problems:

- Building a bridge
- Decreasing a certain type of pollution in a stream
- Constructing a more aerodynamic car
- Reducing erosion
- Attracting birds to a site
- Installing a rain garden
- Increasing the production of a garden
- Reducing animal damage on crops
- Getting rid of (or preventing the growth of) non-native and/or invasive plants
- Determining the population and/or distribution of an animal population
- Constructing a new soccer field that will not flood

Version 1: Define the Problem for an Existing Project

If the project is already known, the teacher or mentor works with students as they revisit their observations (Step 1: Ecosystem Description) related to the project topic. Through a discussion of these observations the teacher can introduce key concepts and explain the project focus.

In the example of an existing project to design and install a rain garden (discussed in *Step 1: Ecosystem Description*), the teacher or mentor works with students as they look through their observations related to stormwater: areas of standing water, saturated ground, and large non-pervious surfaces. Through a discussion of observations, the teacher introduces the concepts of stormwater runoff and rain gardens and explains that the students' project will focus on designing and installing a rain garden on the school campus.

The students then define the problem by writing a clear problem statement. This statement will be entered on the ***Step 3 Student Page A: Researching the Problem*** document.

Example: **Design and install a rain garden that will reduce stormwater runoff.**

Note: Throughout the process of **Define the Problem**, students continually revisit their Ecosystem Description documents - writing new observations in the appropriate sections, collecting data on any investigation forms and continuing to write down questions they have about their observations. Posting observations and data, as well as creating a classroom "parking lot" for questions, validates and encourages students to think inquisitively as they investigate a site.

Version 2: Defining a Problem at a Site

When a teacher or mentor does not have a project in mind, the students must determine a problem and, eventually, a project.

In this instance, as students review their *Ecosystem Descriptions*, they must collaborate and communicate with one another while sorting and evaluating their observations and questions to determine a problem (see ***Step 2 Student Page: Define the Problem***). Through this process, students may realize that one or more problems are obvious or that further observations of the site and/or a field investigation related to the site may be needed before they can clearly define a problem. For an idea of what this process could look like in the classroom, please see the example below.

Returning to the example of the school campus observations, students review their **Step 1 Student Page (A): Ecosystem Description Notes** pages, they discover that a number of students wrote observations about the area of the schoolyard right next to the basketball court that was "mushy" and muddy with large puddles. Additionally, several students recorded questions related to the standing water. As a result, the class may determine that the area next to the basketball court is too wet and muddy.

The students (with teacher guidance) then work to clearly define the problem as: **Reduce the standing water (creating the mud) in the area next to the basketball court.**

However, in some situations, not all students agree on a problem. In the schoolyard example, some students believe that a lack of habitat/nesting areas is also a problem. At this point, the teacher encourages the class to come to a consensus or allows several projects to take place. If a group of students cannot decide as to which problem should become their project, further research and/or observations of the site should take place. Frequently, a class may also need to vote to determine the "top problem."

In some cases, students may not believe that any problems exist. The teacher or mentor must provide the students with focused questions or have the students return to the site to record more specific observations until students have enough information to determine a problem for their project.

Returning to the example of the school campus observations (see ***Step 1: Describing an Ecosystem***), students are aware of standing water on the school site, but they may be unsure if it could be considered a problem. The teacher or mentor can encourage further research (about topics including standing water, stormwater runoff, non-pervious surfaces and flooding), have the students observe the site after/during a rain or guide students as they conduct an investigation by running water through a sprinkler (simulated rain) for a designated period of time in the area to see what happens. After any of these activities, students can utilize the ***Step 2 Student Page: Define the Problem*** document and participate in guided discussions related to the impact of water runoff on the campus, the surrounding area and even student activities. Students may then come to the conclusion that the problem is **too much stormwater runoff is causing the muddy areas and standing water by the basketball court**.

Once the problem is determined, students define the problem by writing a problem statement, which will be entered on the ***Step 3 Student Page A: Research the Problem*** document. Once the problem is determined, students write the problem statement on the ***Step 3 Student Page (A): Research the Problem*** document.

Step 2 Student Page:
Define the Problem

Before you can define and describe a problem, you must first determine the problem. After completing all observations and research for your *Ecosystem Description*, look through your written observations, notes, data and questions as you use the process below to determine one problem that exists on your site.

1. Mark any observations or notes that indicate an obvious problem(s) – one that you know exists – with a star or other symbol you will remember.
2. Next, eliminate (cross a line through) or revise any notes or questions that are vague or unclear.
3. Group the remaining questions and observations either using color highlighters, symbols, or other means of marking. (Or even by typing them on a blank document, cutting, pasting and moving them around.)
4. Look within each group for any *themes or concepts* that show there is a problem – something that could be solved (completed, fixed or changed).
5. If you are still unsure and cannot find a possible problem that could be investigated or solved, work with your teacher and/or peers to further sort through your information. (You may need to revisit your site and/or gather more information.)
6. Once you have determined a problem (the purpose of or reason for your project), define that problem clearly in writing on your ***Step 3 Student Page (A): Researching the Problem*** document.

Step 3: Research the Problem

> **Practices in Science and Engineering**
>
> 2. Developing & Using Models
> 3. Planning & Carrying Out Investigations
>
> See Appendix A

The focus during Step 3 is **the problem itself**, not the potential solutions. Students must gain background information as to the causes, effects and the interconnectedness of their problem with the larger system before they can begin to evaluate and/or design solutions. However, through this process students will undoubtedly come across potential solutions as they research factors that impact the problem. This information can be recorded in the students' notes to be used later during ***Step 5: Determine Possible Solutions***.

As students begin researching the problem, they work cooperatively with their peers to not only determine what they already know, but also what they need to know (see *Step 3 Student Page (A): Research the Problem*). The students also designate the resources that they need, how they will gather information and if further investigations are needed (see *Step 3 Student Page (B): Planning the Research*). Students can use *Step 3 Student Page (C): Project Journal Notes Page* while researching their problem.

The role of the teacher or mentor during this process is one of facilitator. Students are encouraged to take charge of their own learning. However, teachers and mentors can help equip students with the necessary tools for success. Research and questioning skills can be taught during the project-based learning process or through prior activities. Guidance can be provided as students look for information, fine-tune their questions and connect with experts.

> For example, as students begin to research the problem of too much stormwater runoff on their school campus, they first record the information they already know about water and how it behaves. They think about past experiences with water, drainage and flooding. Students also begin to write questions or statements about what they do not know. Throughout the process, the teacher or mentor may guide the students to think about the types of information and questions the students might research: *What is drainage? How does it work? What does non-pervious mean? Where does the water go when it drains? Is there water underground?* Additionally, the teacher may provide lists of resources/websites and/or expert contact information to enable students to more effectively plan their research, determine the resources they will use and design how they might conduct further investigations.

Why Focus on Change Over Time?

Stepping back to consider how a system can change over days/months/years is an important systems thinking skill. It can help students think about long-term and short-term consequences of actions, and to see patterns or cycles less discernible when analyzing a system through a single point in time. By having students create Change Over Time graphs, they can demonstrate higher level thinking skills by predicting whether a particular part of the analysis under study might increase, decrease or oscillate over time.

To illustrate the difference, consider a scenario where new species of fish was introduced into a lake, causing a native species population to decrease. A single-point-in-time question might be, 'what was the native fish population before the new species and/or after the introduction of the new species?' In contrast, a Change Over Time question might ask: what might the happen to the native fish population over 1 year? 5 years? 10 years? Why?

With Change Over Time graphs, different units of time are considered to help think about the ever-changing nature of systems, and students focus on thinking about the patterns rather than graphing precise data points. This type of analysis often offers rich insights that might otherwise be overlooked.

-Nalani Linder, MA

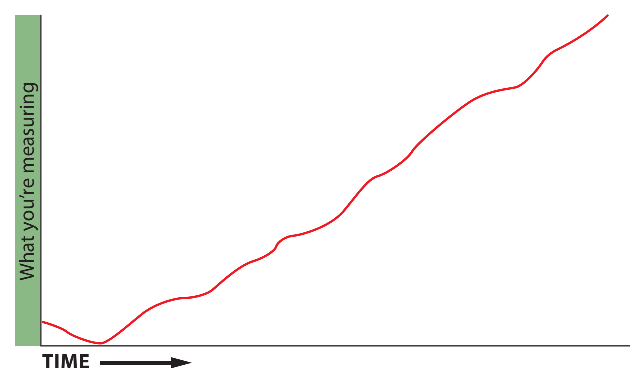
Change Over Time Prediction Graph

Once the students have a more thorough understanding of the problem, they can participate in an optional activity (see Appendix D) through which they look beyond *today* and consider the problem over time – both short-term and long-term. Equipped with new information, the students are able to create *Change Over Time Prediction Graphs* to communicate how they think the problem will change over a given period of time if they do not attempt to solve the problem.

This activity enables students to consider the impacts of the problem on the bigger system, both now and in the future.

Systems thinking is about seeing the world as whole and interconnected. It looks at how parts of a system are connected together and how changes in one part of a system can affect changes in other parts over time.

A **change-over-time graph** shows the pattern of how one or more parts in a system is changing over time.



Step 3 Student Page (A):

Research the Problem

***This is a research *planning* document. Your notes and information should be recorded in your Project Journal Notes pages.**

Once you have determined your problem, write a statement that describes the problem in your own words. Then, begin the research process by determining what you already know, what you need to know and where you might find the information to help you get an in-depth understanding of the problem.

The Problem:

Why is this problem important?

I already know:

I need to know:

Step 3 Student Page (B):

Planning the Research

I will find information from:

(Explain in detail: further investigations and/or data collection needed, resources such websites or books to be used, individuals/groups to contact, etc.)

Step 3 Student Page (C):

Project Journal Notes Page

My Notes:

Resource Citation:

Topics Covered

Step 4: Stakeholder Description

Practices in Science and Engineering

2. Developing & Using Models
3. Planning & Carrying Out Investigations
4. Using Mathematics & Computational Thinking

See Appendix A

Stakeholders are individuals or groups with interests related to an issue or outcome. Every public policy decision, from funding priorities to laws, has an impact on multiple stakeholders, and thus, is frequently influenced by those stakeholders.

As students research the individuals and groups that are connected to their project, they see firsthand that most issues or problems have more than just one or two stakeholders, each of whom may have a different view point in relation to a problem and its potential solutions.

Through the Stakeholder Description, students research at least 2 stakeholders to gain a deeper understanding of the different perspectives surrounding the problem. The more stakeholders they research, the better their understanding of any issues related to the problem. Students should contact Tribes, local, state and federal governments, business and industries, community groups and landowners.

As students gather information about stakeholders, they can look at stakeholder websites*, newsletters or they can even interview individuals and/or group representatives. Information gathered can be compiled and shared/presented to fellow students in a written format, or if desired, as commercials or advertisements. The key is for students to finish Step 4 with an enhanced understanding of the stakeholders' perspectives related to the project problem.

After completing the Stakeholder Description, students will then be able to take into account the different stakeholder concerns and interests, as well as any points of contention among stakeholders, as they research and determine the best possible solution(s) for a problem. While students do not necessarily need to cater to every stakeholder group, more often than not, they do need to seek approval, funding and/or land access from a stakeholder or multiple stakeholders to carry out a solution. Awareness of stakeholder perspectives will enhance the students' abilities to design their solution/project plans, requests and/or presentations so that they accomplish their goals while also addressing stakeholder interests and/or concerns.

Students should make sure they are looking at the stakeholder's website, not a third party website with information about the stakeholder.

For example, if students determined that poor drainage next to the basketball courts was the problem, their stakeholders would be those individuals and groups connected to the school campus. Such stakeholders would include the district office, principal, school staff, custodian and even students who use the basketball court and/or field next to the court.

As students begin researching the stakeholders, they gain an increased understanding about various interests and concerns:

- The school district is concerned that drastically changing the school grounds (such as putting in drains or a rain garden) would be expensive and difficult to maintain long-term. As a result, the district would rather just leave the soggy area (and puddle when it rains) next to the basketball court alone.
- The principal and staff are frustrated with the poor drainage problem. An increased amount of time must be spent roping off the area, re-directing students and retrieving basketballs. However, they do not want to see funds for school programs and field trips redirected to pay to fix the problem.
- The custodian is also concerned about the poor drainage. Before school and during recesses, some students get very muddy and track it into the school, making more clean-up necessary. He likes the idea of fixing the problem, but is concerned that long-term maintenance will become his responsibility, thus resulting in more work.
- The students who enjoy playing on the basketball court also express frustration about continually having to stop playing their game to fish the ball out of the mushy area/puddle. They want the area fixed as long as they can still play basketball.

As students continue their project by looking for potential solutions, their knowledge of stakeholder perspectives will assist with determining the benefits, limitations and feasibility of each possible solution.

Note: Teachers and mentors may need to remind students to record all the sources they use for research on their Annotated Bibliographies.

Step 4 Student Page:
Stakeholder Description Notes, Page 1

- Stakeholder Group/Name (Person, Agency/Organization/Business):
- Web address:
- Phone Number:
- Representative Name (if business/agency/organization contacted):
- How is this stakeholder connected to the problem? (For example: owns the land where the problem is occurring, works where the problem exists, etc.)
- Is the stakeholder aware of the problem? If so, does the stakeholder have any opinions (concerns or positive comments) related to the problem?
- How might the problem affect or impact the stakeholder now and in the future? Give details.
- How might the **stakeholder** affect or impact the problem and/or possible solutions now and in the future? Give details.
- Would the stakeholder like to play a role this project, such as sharing their knowledge of the problem or helping with finding a solution to the problem? If so, what role? (speaking to the class, helping provide resources, participating in field work or data collection, etc.)

Step 4 Student Page:

Stakeholder Description Notes, Page 2

- Stakeholder Group/Name (Person, Agency/Organization/Business):

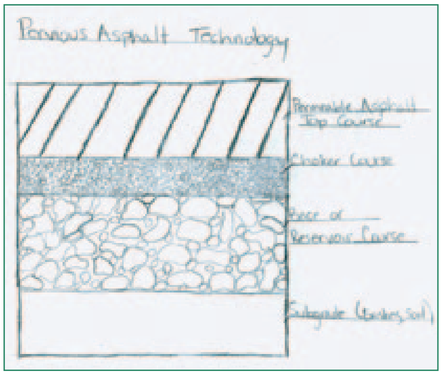
- If the stakeholder owns land where the project is taking place:
  - How does the stakeholder currently use the land? (If the land is leased to another group for use, please list the group and how that group uses the land.)
  - Does the use of the land impact the problem? How?
  - Are any efforts taken to ensure environmentally-friendly practices on the land? If so, what are they?
  - Are there any laws that affect the way the stakeholder can use/impact the land?
  - If the stakeholder is an individual or family group, are there any cultural or family connections that tie him/her/them to the land? Please describe. (Retell a story, explain the connection, etc.)

Step 5: Determine Possible Solutions

Practices in Science and Engineering

6. Constructing Explanations & Designing Solutions
7. Engaging in Argument from Evidence

See Appendix A



Frequently, problems that students discover on their school campus or a local site will not be completely new. Someone may have already addressed and solved or attempted to solve the same, or at least a similar, problem. In fact, as students research possible solutions to a problem, they will most likely find a number of different alternatives, each with its own set of benefits and consequences.

This information can be of great value to students during *Step 5: Determine Possible Solutions.* Students complete the *Step 5 Student Page: Comparison Table of Possible Solutions* by researching and recording what others have proposed or done in similar situations and/or write up original ideas while evaluating each solution based on the following criteria:

- **Summary of the possible solution**
  (Describe the solution in terms of who, what, how, when and where.)
- **Positive impacts on the environment**
  (What will the solution do for a local ecosystem and/or the Puget Sound/Pacific ocean?)
- **Potential negative consequences (Trade-offs)**
  (What might result from the solution that would be damaging, harmful or not desired?)
- **Stakeholder perspectives**
  (How might stakeholders view the solution? What might they like or dislike?)
- **Limitations**
  (What might hold back or make the solution difficult? Consider cost, time, liability, etc.)
- **Feasibility (Reasonableness**)

(Rate the solution on a scale from 1 to 5, with 1 being not possible to complete and 5 being a realistic and doable project.)

Upon completion of the ***Comparison Table of Possible Solutions*** document, students then narrow down their list of possible solutions by rating and comparing the evaluation criteria. Through this evaluation process, each student develops an increased awareness of the interconnectedness of actions, as well as the complexity of decision making in relation to the environment. He or she also determines the best possible solution to the problem, and as a result, the project.

Note: You can use *Sustainable Tomorrow* (PEI, 2011) to develop models for analysis.

Step 5 Student Page:
Determine Possible Solutions

Now that you know have a clear understanding of the problem you are trying to solve (including stakeholder opinions), you are ready to brainstorm possible solutions to the problem and to determine your project.

During your research to learn more about the problem, you probably discovered that someone may have already solved, or attempted to solve, a similar problem. You may also have some of your own ideas as to a possible solution to the problem. Each possible solution will have its own set of positive benefits and negative consequences.

To determine the best possible solution to the problem you wish to solve, follow this process using the ***Step 5 Student Page: Comparison Table of Possible Solutions***. Keep in mind that no solution is perfect!

1. **Create a *Possible Solutions* list.**

   Write down all possible solutions on the student page that you learned about during your research as well as any original ideas. You may need to do more research about the problem and its possible solutions. Be sure to document all of the sources you use on your Bibliography.

2. **Narrow your list.**

   Read through your list and cross off any ideas on your *Possible Solutions* that do not interest you or that seem unrealistic* (for example, solutions that would be way too expensive, require way too much expertise, or would take longer than the time you have available).

   *Keep in mind that many projects will require some money for purchasing equipment and/or experts to provide help. This does not mean a project is not doable. Many groups and businesses are willing to donate materials and/or their time to help students complete meaningful projects!

3. **Determine top 3 or 4 solutions.**

   Continue to narrow your list until you have 3 or 4 possible solutions. Summarize those solutions in the first column (one on each row) of the **Step 5 Student Page: Comparison Table of Possible Solutions.**

4. **Compare solutions.**

   Briefly describe the details of each solution for the following categories:

   Summary of the possible solution
   (Describe the solution in terms of who, what, how, when and where.)

   Positive impacts on the environment
   (What will the solution do for a local ecosystem and/or the Puget Sound?)

   Potential negative consequences (Trade-offs)
   (What might result from the solution that would be damaging, harmful or not desired?)

Step 5 Student Page:

Determine Possible Solutions

Stakeholder perspectives
(How might stakeholders view the solution? What might they like or dislike?)

Limitations
(What might hold back or make the solution difficult? Consider cost, time, liability, etc.)

5. **Rate the solutions.**

   Once you have described each solution, give each a *Feasibility Rating* that determines if it is reasonable and realistic for you to complete. The ratings should be on a scale from 1 to 5, with 1 being not possible to complete and 5 being a realistic and doable project. (Remember, perfect solutions do not exist!)

6. **Choose the *best* solution for your project.**

   Look over the comparison table. Choose the solution with the highest rating and/or a highly rated solution that seems most interesting. Once you have approval from your teacher, that solution will be your project.

Example: Step 5 Student Page: Comparison Table of Possible Solutions

Summary of Possible Solutions	Positive Impacts on the Environment	Potential Negative Consequences (Trade-offs)	Stakeholder Perspectives	Limitations	Feasibility Rating
Describe the solution in terms of who, what, how, when and where.	What will the solution do for a local ecosystem and/or the Puget Sound/Pacific Ocean both now and in the future?	What might result from the solution that would be damaging, harmful or not desired both now and in the future?	How might stakeholders view the solution? What might they like or dislike?	What might hold back or make the solution difficult? Consider cost, time, liability, etc.	Rate on a scale from 1 to 5
Put in a rain garden by the basketball court: -We students will plan, gather plants and create it -During Science classes, in the spring	-It captures water and allows it to return to the water cycle slowly. -It cleans out pollution from the water as it soaks in. So, it protects the Puget Sound.	-Could flood onto playground if not built correctly. -Could be vandalized -The plants might die and we'd have to buy more.	-District people are not sure who will take care of it when we move on to other schools. -Teachers and students like the idea of doing something for the environment.	-Expensive – we would need to get some plants and soil donated -We need equipment like an excavator – need to find someone to help.	4
Install French Drains below the basketball court -We would work with the school district -After the rainy season	The water would be captured underground and would eventually go into the earth or water table.	-The drains could clog and cause more flooding. -Students might not get to play where there are drains.	-District and school people worried the rest of the playground will get damaged while installing the drains.	-French Drains are very expensive. -We would need to get permits and pay someone to put in the drains.	1

Step 5 Student Pages:

Comparison Table of Possible Solutions

Summary of Possible Solutions	Positive Impacts on the Environment	Potential Negative Consequences (Trade-offs)	Stakeholder Perspectives	Limitations	Feasibility Rating
Describe the solution in terms of who, what, how, when and where.	What will the solution do for a local ecosystem and/or the Puget Sound/Pacific Ocean both now and in the future?	What might result from the solution that would be damaging, harmful or not desired both now and in the future?	How might stakeholders view the solution? What might they like or dislike?	What might hold back or make the solution difficult? Consider cost, time, liability, etc.	Rate on a scale from 1 to 5
1.					
2.					
3.					

Step 5 Student Pages:

Comparison Table of Possible Solutions, Version 2

Define the Problem:

Why is this Problem Important?

Summary of Possible Solutions	Positive Impacts on the Environment	Potential Negative Consequences (Trade-offs)
Describe the solution in terms of who, what, how, when and where.	What will the solution do for a local ecosystem and/or the Puget Sound/Pacific Ocean both now and in the future?	What might result from the solution that would be damaging, harmful or not desired both now and in the future?
1.		
2.		
3.		

Stakeholder Perspectives	Limitations	Feasibility Rating
How might stakeholders view the solution? What might they like or dislike?	What might hold back or make the solution difficult? Consider cost, time, liability, etc.	Rate on a scale from 1 to 5

Step 6: Develop a Plan: Identify, Plan and Reflect on Your Project

Practices in Science and Engineering

5. Using Mathematics & Computational Thinking
6. Constructing Explanations & Designing Solutions
7. Engaging in Argument from Evidence

See Appendix A

During ***Step 6***, students work collaboratively to develop a **Project Plan** to address the problem - identifying required resources and steps needed for implementation, as well as reflecting on the potential outcomes of the solution.

While some of this information is communicated during ***Step 5: Determine Possible Solutions***, students will need to conduct additional research to further describe the project in terms of connections to the bigger picture, costs, procedures, limitations, and evaluation criteria. Additionally, as students gather information, they should record the names and contact information of local experts (including stakeholders) that may be available to provide valuable input during the plan writing process, as well as resources or expertise during the project implementation.

The Step 6 Student Page (A): *Project Plan* is the document students will use to guide their project. It must be well thought-out and thorough. Teacher or mentor oversight and monitoring of the plan development are crucial. Small group or class meetings to discuss components of the plan are beneficial for students in that they receive specific guidance, as well as to teachers in that they can gauge student understanding and progress. Additionally, if small groups within a class are working on the same project, class meetings allow for student communication and collaboration to create a master *Project Plan* for the class.

A separate, but equally important, component of the *Project Plan* is the Step 6 Student Page (B): *Pre-Project Reflection.* Through this simple reflection, teachers are able to assess student understanding and comfort levels, and provide additional guidance and/or project adjustments as needed.

While the *Pre-Project Reflection* is a useful tool for student communication with the teacher or mentor, the *Project Plan* is a valuable tool for student communication with stakeholders, particularly stakeholders that must approve a project. The components of the *Plan* can be presented easily as slides within a PowerPoint or other presentation program*. After the students present to the teacher, mentor and/or stakeholders, they should make adjustments and/or corrections, as needed. Once the *Project Plan* is complete and approved, the students are ready to implement the project.

*If students present to stakeholders, they should be provided ample opportunities for practice and review by the teacher or mentor <u>before</u> their presentation.

Step 6 Student Page (A):
Project Plan

Now that you have determined the best possible solution to the problem, you have determined your project. While filling out the ***Step 5 Student Page: Comparison Table of Possible Solutions,*** you gave a brief description of your project. Use the details from that table, plus additional information gathered through further research, to identify and plan your project.

Notes

Purpose: What is the *problem*?

Location: Where is the problem? Be as specific as possible.

Summary: In one to three sentences, summarize your project (the *solution to the problem).*

Connections: Describe how this project connects to the bigger picture: the surrounding ecosystem. How will it impact the region (both positively and negatively)?

Costs/Budget: If needed, create a table of predicted costs/expenses.

Step 6 Student Page (A):

Identify and Plan Your Project

Project Plan Notes - continued

Procedure: Create a timeline (with or without actual dates) of the key steps you will take to complete your project. (Keep in mind any further research and/or investigations you will need to complete. In addition, plan for time to evaluate, and possibly adjust, your project plan during the process.)

Limitations and Challenges: What might interfere with or cause problems during your project? How will you prepare for these limitations/challenges?

Evaluation: How will you measure the success of your project? In other words, how will you prove it turned out like you planned? Develop a list of criteria (or standards) that you will use at the end of your project to prove it was successful. The criteria can include measurements and/or statements.

> **For example,** if your project was to install a rain garden, the criteria could include simple criteria – *During an actual or simulated rain, the rain garden will prevent puddles from forming by the basketball court*. Or more specific criteria - *During an actual or a simulated rain, the rain garden will capture and hold all of the water coming off the basketball court.* OR *The rain garden will capture and hold the stormwater runoff from 4,200 square feet of asphalt (the basketball court) and will completely drain within 24 hours.*

Contacts: List all contacts (name, title/job, business/organization, email, and phone) for this project. Be sure to include project teammates, experts and stakeholders.

Step 6 Student Page (B):

Pre-Project Reflection

After you complete *Step 6 Student Page (A): Identify and Plan your Project,* spend some time thinking about your plan and the following questions:

1. What role will you play with this project?
2. What excites you?
3. What worries you?

Share your responses through one of the following options:

- **Writing:** Write a one paragraph summary (5-6 sentences) that answers the questions above.
- **Art:** Create an original work of art in any medium of choice (such as painting, drawing or sculpture). Be sure to communicate your responses to the questions above.
- **Creative writing:** Create a skit, commercial, or persuasive letter to yourself that communicates your responses to the questions above.

Notes/Draft:

Step 7: Implement the Plan: Tracking Progress through Field Notes

Practices in Science and Engineering

5. Using mathematics & Computational Thinking
6. Constructing Explanations & Designing Solutions
7. Engaging in Argument from Evidence

See Appendix A

Throughout the implementation of a project, students must continually monitor and communicate their progress not only to their peers, but also to teachers, mentors and/or stakeholders. The ***Step 7 Student Page: Field Notes*** document is used by students as they report on their projects daily, weekly or after each major task. It provides a structured format for communicating about recent activities, recording any changes made to the *Step 6 Student Page (A): Project Plan* and reflecting upon the impact and value of each step of the process.

Prior to any project, the *Field Notes* page should be altered by teachers, mentors and/or students to accurately depict the components of the project. For example, students may need to record specific data/ measurements or create diagrams/drawings to thoroughly communicate the project's progress. In addition, the *Field Notes* document should always include questions that allow students to reflect upon the value of a project and how it impacts the "bigger picture".

Upon completion of the project, the *Field Notes* documents are compiled into a chronological record of activities, challenges and impacts of the project and are utilized as the students summarize, evaluate and present a project.

Step 7 Student Page:
Field Notes

As you implement or carry out your plan, fill out a *Field Notes* page daily, weekly or each time you complete a major task related to your project.

Field Notes

Date:

Who: List the individual(s) you worked with.

Location: Be as specific and include latitude and longitude, if needed.

Activity: Describe what you did.

Role of Activity: Write a brief description of how your participation in today's activity will impact your project and/or **the Puget Sound**.

Process: Is your project going the way you planned? Do you need to change your *Project Plan* in any way? If so, **how** (modify schedule – more or less time, changes in equipment/materials list, different process steps needed)? **Be sure to record changes on your actual *Project Plan*.**

Next Steps: What are the next steps in your process?

Step 8: Summarize, Evaluate and Reflect

Practices in Science and Engineering

7. Engaging in Argument from Evidence
8. Obtaining, Evaluating, and Communicating Information

See Appendix A

The culmination of the Pacific Education Institute's *Project-Based Learning Model* is the presentation of a *Step 8 Student Page: Project Summary, Evaluation and Reflection.* Students communicate their experiences while summarizing and assessing a project's process and outcomes. They consider the criteria for success described in the *Project Plan* as they determine the project's effectiveness. In addition, students reflect upon the environmental impacts of the project, intended and unintended, as well as the influence the project had upon themselves.

The *Project Summary, Evaluation and Reflection* is designed so students can easily and effectively develop a presentation with each section serving as a separate visual (such as a PowerPoint slide) and/or major talking point. As in the case of the *Step 6 Student Page: Project Plan,* teachers and/or mentors should provide students with ample opportunities for practice and review before public presentations.

Once prepared, students present to their peers, stakeholders and/or community members, communicating the reasons, structure and positive environmental impacts of their project. The students further internalize the value of their project and the audience learns about efforts to restore or protect natural components of their community.

Step 8 Student Page:

Project Summary, Evaluation and Reflection

Use the statements and questions below to prepare a presentation about your project. (Refer to the documents and *Field Notes* that you created during your project, as needed.)

1. Team Members
   List the individuals you worked with to complete this project.

2. Briefly describe the *Problem* you worked to solve.

3. Explain the importance of this problem and how it connects to/affects the larger region (such as the Puget Sound or Columbia River Basin).

4. Identify the stakeholders you worked with, as well as other stakeholders who had an interest in your project.

5. Summarize your project, including any unexpected challenges, changes made to your original plan and major activities.

Step 8 Student Page:

Project Summary, Evaluation and Reflection, p. 2

6. Describe the success of the project. Look back at the *Evaluation* section of your *Project Plan* and discuss how the end result of your project met or didn't meet those criteria.

7. Describe any unintended consequences that resulted from your project. (Did anything happen as a result of your project that you didn't expect or plan?)

8. Did your opinions and/or perspectives change related to your project? How? Why or why not?

9. Acknowledge any other individuals you worked with or who assisted you during this project/ experience.

10. If you are presenting this summary, be prepared for questions from your audience.

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Glossary

Analysis: A systematic, detailed examination intended to a (1) define or clarify problems, (2) inform design decisions, (3) predict or assess performance, (4) determine economic feasibility, (5) evaluate alternatives, or (6) investigate failures. (NSE & NRC 2009).

Changes Over Time Graph: A **change-over-time graph** shows the pattern of how one or more parts in a system is changing over time.

Components: Distinct parts of an object or system.

Design Process: The process of originating and developing a plan for product, structure, system, or component to meet a human need or want.

Ecosystem: A natural unit consisting of all plants, animals, and microorganism (biotic factors) in an area functioning together with all of the nonliving physical (abiotic) factors of the environment.

Engineering Design: A purposeful, iterative process with the explicit goal governed by specifications and constraints.

Evaluation: To make judgments or appraisals based on collected data.

Feasibility (for project solution): Reasonable and realistic to complete.

Geographic Information System: A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information (ESRI).

Interactions: The mutual influences among variables in a system or between subsystems, which may be correlational or causal.

Modeling: A graphical, physical, or mathematical representation of the essential features of a system or process that facilitates engineering design. (NAE & NRC 2009).

Problem: A challenge that can be solved through the design process.

Solution: A device or process created through technological design to meet a human need or want.

Stakeholders: Individual or groups with interests related to an issue or outcome.

Systems Thinking: Seeing the world as a whole and interconnected. Systems thinking looks at how parts of a system are connected together and how changes in one part of a system can affect changes in other parts over time.

Technology: Any modification of the natural world made to fulfill human needs or desires (NAS, 2011).

Trade Offs: Decisions made to relinquish or reduce one attribute of a design on order to maximize another attribute (NAE & NRC 2009).

Unintended Consequences: Unplanned or unexpected events or situations occurring as a result of an action taken.

Appendix A : Distinguishing Practices in Science from those in Engineering: Framework for K-12 Science Education (NRC, 2011)

1. Asking Questions and Defining Problems	
Science begins with a question about a phenomenon, such as “Why is the sky blue?” or “What causes cancer?” and seeks to develop theories that can provide explanatory answers to such questions. A basic practice of the scientist is formulating empirically answerable questions about phenomena, establishing what is already known, and determining what questions have yet to be satisfactorily answered.	**Engineering** begins with a problem, need or desire that suggests an engineering problem that needs to be solved. A societal problem such as reducing the nation’s dependence on fossil fuels may engender a variety of engineering problems ,such as designing more efficient transportation systems, or alternative power generation devices such as improved solar cells. Engineers ask questions to define the engineering problem, determine criteria for a successful solution, and identify constraints.
2. Developing and Using Models	
Science often involves the construction and use of a wide variety of models and simulations to help develop explanations about natural phenomena. Models make it possible to go beyond observables and imagine a world not yet seen. Models enable predictions of the form “if . . . then . . . therefore” to be made in order to test hypothetical explanations.	**Engineering** makes use of models and simulations to analyze existing systems so as to see where flaws might occur or to test possible solutions to a new problem. Engineers also call on models of various sorts to test proposed systems and to recognize the strengths and limitations of their designs.
3. Planning and Carrying Out Investigations	
Scientific investigation may be conducted in the field or the laboratory. A major practice of scientists is planning and carrying out a systematic investigation, which requires the identification of what is to be recorded and, if applicable, what are to be treated as the dependent and independent variables (control of variables). Observations and data collected from such work are used to test existing theories and explanations or to revise and develop new ones.	**Engineers** use investigation both to gain data essential for specifying design criteria or parameters and to test their designs. Like scientists, engineers must identify relevant variables, decide how they will be measured, and collect data for analysis. Their investigations help them to identify how effective, efficient, and durable their designs may be under a range of conditions.
4. Analyzing and Interpreting Data	
Scientific investigations produce data that must be analyzed in order to derive meaning. Because data usually do not speak for themselves, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Sources of error are identified and the degree of certainty calculated. Modern technology makes the collection of large data sets much easier, thus providing many secondary sources for analysis.	**Engineers** analyze data collected in the tests of their designs and investigations; this allows them to compare different solutions and determine how well each one meets specific design criteria—that is, which design best solves the problem within the given constraints. Like scientists, engineers require a range of tools to identify the major patterns and interpret the results.
5. Using Mathematics and Computational Thinking	

In **science**, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks, such as constructing simulations, statistically analyzing data, and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable predictions of the behavior of physical systems, along with the testing of such predictions. Moreover, statistical techniques are invaluable for assessing the significance of patterns or correlational.	In **engineering,** mathematical and computational representations of established relationships and principles are an integral part of design. For example, structural engineers create mathematically-based analyses of designs to calculate whether they can stand up to the expected stresses of use and if they can be completed within acceptable budgets. Moreover, simulations of designs provide an effective test bed for the development of designs and their improvement.
6. Constructing Explanations and Designing Solutions	
The goal of **science** is the construction of theories that can provide explanatory accounts of features of the world. A theory becomes accepted when it has been shown to be superior to other explanations, in the breadth of phenomena it accounts for, and its explanatory coherence and parsimony. Scientific explanations are explicit applications of theory to a specific situation or phenomenon, perhaps with the intermediary of a theory-based model for the system under study. The goal for students is to construct logically coherent explanations of phenomena that incorporate their current understanding of science, or a model that represents it, and are consistent with the available evidence.	**Engineering** design, a systematic process for solving engineering problems, is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, technological feasibility, cost, safety, esthetics, and compliance with legal requirements. There is usually no single best solution but rather a range of solutions. Which one is the optimal choice depends on the criteria used for making evaluations.
7. Engaging in Argument from Evidence	
In **science**, reasoning and argument, are essential for identifying the strengths and weaknesses of a line of reasoning and for finding the best explanation for a natural phenomenon. Scientists must defend their explanations, formulate evidence based on a solid foundation of data, examine their own understanding in light of the evidence and comments offered by others, and collaborate with peers in searching for the best explanation In engineering, reasoning and argument are essential for finding the best possible solution to a problem.	**Engineers** collaborate with their peers throughout the design process, with a critical stage being the selection of the most promising solution among a field of competing ideas. Engineers use systematic methods to compare alternatives, formulate evidence based on test data, make arguments from evidence to defend their conclusions, evaluate critically the ideas of others, and revise their designs in order to achieve the best solution to the problem at hand.
8. Obtaining, Evaluating, and Communicating Information	
Science cannot advance if scientists are unable to communicate their findings clearly and persuasively or to learn about the findings of others. A major practice of science is thus the communication of ideas and the results of inquiry—orally, in writing, with the use of tables, diagrams, graphs, and equations, and by engaging in extended discussions with scientific peers. Science requires the ability to derive meaning from scientific texts (such as papers, the Internet, symposia, and lectures), to evaluate the scientific validity of the information thus acquired, and to integrate that information.	**Engineers** cannot produce new or improved technologies if the advantages of their designs are not communicated clearly and persuasively. Engineers need to be able to express their ideas, orally and in writing, with the use of tables, graphs, drawings, or models and by engaging in extended discussions with peers. Moreover, as with scientists, they need to be able to derive meaning from colleagues' texts, evaluate the information, and apply it usefully. In engineering and science alike, new technologies are now routinely available that extend the possibilities for collaboration and communication.

Appendix B: Preparing Students to Conduct Field Investigations

Excerpt from Field Investigations: Using Outdoor Environments to Foster Student Learning of Scientific Processes (PEI 2007)

Part 1: What Questions Can I Investigate?

Objectives

Students will:

1) distinguish between three different types of investigative questions, and
2) suggest questions that can be asked about the natural world.

Science Grade Level Expectation

Questioning: Understand how to ask a question about objects, organisms, and events in the environment.

Thinking Skills

Comparing/Contrasting, Classifying

Learning Experience

Students sort investigative questions into three categories (descriptive questions, comparative questions, and correlative questions).

Materials

- **Sets of Investigative Questions** (one set per three students). Copy questions onto card stock and cut into sentence strips; lace in an envelope.
- **Handout.** Three types of field investigation questions.
- **Question on Board:** Given the categories descriptive, comparative, and correlative, how would you categorize the set of questions in your envelope?

Background

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? These essential questions about the relationships between humans and the environment cannot be answered with one field investigation.

Asking a testable question is central to scientific inquiry. The following lesson is geared to help students think about the ways questions are asked and the types of questions field investigators research. There are three types of field investigations—descriptive, comparative, and correlative.

Descriptive field investigations involve describing parts of a natural system. Scientists might try to answer descriptive questions such as, "Where do cougars go when their habitat gives way to a new housing development?" or "What areas do cougars select for den locations?"

In comparative field investigations, data is collected on different populations, or under different conditions (e.g., times of year, locations), to make a comparison. A researcher might ask a comparative question such as, "Is there a difference in lichen growth in areas of high pollution and areas of low pollution?"

Correlative field investigations involve measuring or observing two variables and searching for a pattern. These types of investigations are typically not explored until high school. Correlative questions focus on two variables to be measured together and tested for a relationship: "Do animal tracks increase with greater forest canopy cover?" "Does the salmon population go down when dissolved oxygen concentrations go down?"

There are many types of questions. In addition to the three types of investigative questions, students may ask **essential** questions, **why** questions and book/internet **research** questions.

Lesson

Focus

1. Review the essential questions. These big picture questions are why we conduct field investigations. 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?

2. Distribute the handout and discuss the three types of field investigation questions. You might ask students questions to help them notice differences in the three types of questions.
   - What patterns do you notice in each type of question?
   - What words are important to look for when identifying each type of question?

Explore

3. Divide the class into teams of three. Hand each team an envelope set of investigative questions, and ask them to sort the questions into three categories—descriptive, comparative, and correlative.

Reflect

4. Give the teams time to think about each question and agree on the categories. You can facilitate this process by asking the questions below as you circulate the room.
   - Did you all agree to this category? Explain how you came to this decision.
   - Can each one of you come up with a justification as to why these questions fall into the categories they do?
   - Do you have an uncertainty pile…if so, why? What more do you need to know?
   - What questions do you have about your categories?
   - Can you write your own examples of each type of question?

5. After about 10 minutes, have the class share their categories by asking about a sample of the questions you handed out. With a chart at the front of the class, have students from various groups place a question in the category they selected and have them say why they chose that category.

6. Discuss why scientists need to think about the questions they pose before working in the field.

Assessment

As students categorize the questions ask them to justify how they classified each question, and ask them to identify the patterns they notice in each type of question (e.g., descriptive questions often begin with "how many," "when," or "where").

Some questions may fit more than one category; what is important is that students can justify their thinking for each category. For example, students may identify the question, "What is the air temperature at your school throughout the year?" as descriptive, because they would be documenting the temperature of a specific location. Other students may call it a comparative question, because they could use the collected temperature data to compare two different times of year.

Three Types of Field Investigation Questions

Descriptive Questions

Descriptive field investigations involve describing parts of a natural system. Descriptive questions focus on measurable or observable variables that can be represented spatially in maps or as written descriptions, estimations, averages, medians, or ranges.

- How many _____ are there in a given area?
- How frequently does _____ happen in a given period?
- What is the [temperature, speed, height, mass, density, force, distance, pH, dissolved oxygen, light density, depth, etc.] of ______?
- When does _____ happen during the year? (flowering, fruit, babies born)
- Where does_____ travel over time? (What is an animal's range?)

Comparative Questions

In comparative field investigations data is collected on different groups to make a comparison. Comparative questions focus on one measured variable in at least two different (manipulated variable) locations, times, organisms, or populations.

- Is there a difference in ______ between group (or condition) A and group B?
- Is there a difference in ______ between (or among) different locations?
- Is there a difference in ______ at different times?

Correlative Questions

Correlative field investigations involve measuring or observing two variables and searching for a pattern. Correlative questions focus on two variables to be measured and tested for a relationship.

- What is the relationship between variable #1 and variable #2?
- Does _____ go up when _____ goes down?
- How does _____ change as _____ changes?

Investigative Questions for Sorting

Copy these questions on to card stock and cut into sentence strips

Does more salal (type of plant) grow in riparian, forest, or field habitats?

Are more insects found in the schoolyard in September, October, or November?

Is wind speed greater near the building or out on the playground in March?

Where do you find the most pill bugs (isopods): under a log, under a pot, or under bushes?

Which habitat (in the forest, in a field, or by a stream) has the greatest percentage of sand in the soil?

Are soil temperatures the coolest at a depth of 5cm, 10cm, or 15cm?

In April, which twigs grow faster, those on maple trees or those on sweet gum trees?

Are traffic sounds louder in front of the school or behind the school?

How many Pileated Woodpeckers live in Schmitz Park?

How many deer live in Olympic National Park?

How many eggs does a salmon lay in the fall in Longfellow Creek?

How often do Swallowtail Butterflies lay eggs in a season in Eastern Washington?

What is the depth of McLane Creek at Delphi Road in September?

What is the air temperature at your school throughout the school year?

What kinds of plants grow in ___ Forest?

What types of birds use the school habitat during the school year?

When do robins in western Washington nest?

When do hemlock trees pollinate?

What is the range of black bears living in Snoqualmie Pass?

What is the number and range of cougars in the Cle Elum, Roslyn area?

Is there a difference in the size of the range of a screech owl or barred owl in Washington's lowland forests?

Are mature (greater than 30 cm diameter) conifer trees taller than mature deciduous trees in the Olympic Rain Forest?

Which location (under bushes, open grass, or on black top) has the highest temperature at 7:00 a.m. at Cedar River Middle School?

Are there more black bears per acre on Snoqualmie Pass or Olympic National Forest?

Are there more snowberry bushes near streams or away from streams in the Grasslands/Steppe in eastern Washington?

Are deer more active during the dawn or the dusk in____?

Do more ferns grow close to the water or away from the water?

Do tree species, tree density, tree diameter, or tree height differ between north and south facing slopes in ___?

Do temperatures differ between forested and non-forested streams in____?

Do birds sing more from 8:30-9:00 a.m. or from 3:00-3:30 p.m.?

How does Douglas-fir seed production time change as elevation changes in the North Cascade Mountains?

How does dissolved oxygen change as water temperature goes up in ___ stream?

How do mouse populations change as hawk populations increase in Puget Sound area?

How do heron populations change as eagle populations increase in the Puget Sound watershed?

As elevations increase, how does the number of Grand Fir trees per acre change in the South Cascades?

What is the relationship between number of days over 60 F in the spring and germination of _____ seeds (or time of flowering)?

What is the relationship between the amount of sunshine and red color in leaves in fall?

How does pH affect the number of salmon eggs hatching in a stream?

Investigative Questions Sorting Key

Descriptive

- How many Pileated Woodpeckers live in Schmitz Park?
- How many deer live in Olympic National Park?
- How many eggs does a salmon lay in the fall in Longfellow Creek?
- How often do Swallowtail Butterflies lay eggs in a season in Eastern Washington?
- What is the depth of McLane Creek at Delphi Road in September?
- What is the air temperature at your school throughout the school year?*
- What kinds of plants grow in ___ Forest?
- What types of birds use the school habitat during the school year?*
- When do robins in western Washington nest?
- When do hemlock trees pollinate?
- What is the range of black bears living in Snoqualmie Pass?
- What is the number and range of cougars in the Cle Elum Roslyn area?

Comparative

- Does more salal (type of plant) grow in riparian, forest, or field habitats?
- Are more insects found in the schoolyard in September, October, or November?
- Is wind speed greater near the building or out on the playground in March?
- Where do you find the most pill bugs (isopods): under a log, under a pot, or under bushes?
- Which habitat (in the forest, in a field, or by a stream) has the greatest percentage of sand in the soil?
- Are soil temperatures the coolest at a depth of 5cm, 10cm, or 15cm?
- In April, which twigs grow faster, those on maple trees or those on sweet gum trees?
- Are traffic sounds louder in front of the school or behind the school?
- Is there a difference in the size of the range of a screech owl and barred owl in Washington's lowland forests?
- Are mature (greater than 30 cm diameter) conifer trees taller than mature deciduous trees in the Olympic Rain Forest?
- Which location (under bushes, open grass, or on black top) has the highest temperature at 7:00 a.m. at Cedar River Middle School?
- Are there more black bears per acre on Snoqualmie Pass or Olympic National Forest?
- Are there more snowberry bushes near streams or away from streams in the Grasslands/Steppe in eastern Washington?
- Are deer more active during the dawn or the dusk in____?
- Do more ferns grow close to the water or away from the water?
- Do tree species, tree density, tree diameter, or tree height differ between north and south facing slopes in ___?
- Do temperatures differ between forested and non-forested streams in____?
- Do birds sing more from 8:30-9:00 a.m. or from 3:00-3:30 p.m.?

Correlative

- How does Douglas-fir seed production time change as elevation changes in the North Cascade Mountains?*
- How does dissolved oxygen change as water temperature goes up in ___ stream?
- How do mouse populations change as hawk populations increase in Puget Sound area?
- How do heron populations change as eagle populations increase in the Puget Sound watershed?
- As elevations increase, how does the number of Grand Fir trees per acre change in the South Cascades?*
- What is the relationship between number of days over 60 F in the spring and germination of _____ seeds (or time of flowering)?
- What is the relationship between the amount of sunshine and red color in leaves in fall?
- How does pH affect the number of salmon eggs hatching in a stream?

*Some questions could fall into a different category depending on how the investigation is set up.

Section 2: Preparing Students to Conduct Field Investigations

Part 2: Descriptive Field Investigation
What Plants and Animals Use the Schoolyard Habitat?

Objectives

Students will:

1) observe an outdoor area,
2) represent their observations using pictures, numbers, words, labeled diagrams, and
3) pose descriptive and comparative questions based on their observations.

Science Grade Level Expectation

Characteristics of Living Matter: Observe and describe characteristics of living organisms.

Planning and Conducting Safe Investigations: Plan and conduct an observational investigation that collects information about characteristics or properties.

Thinking Skills

Observing, Finding Evidence

Learning Experience

Students will conduct a descriptive investigation by observing a particular outdoor area.

Materials

Per Class

Field Guides

Per Pair of Students

Hula Hoops
Yard or Meter sticks
Tape Measures
Colored Pencils
Paint Chips (to help name as many different forms of the "same" color, e.g., green)

Per Student

Clipboards
Ruler
Hand Lenses

Background

In descriptive field investigations researchers describe parts of a natural system. This lesson helps students learn how to conduct a descriptive field investigation of a specific site. Although it is not a long-term study focused on identification of organisms, students observe a large area and a small study area. Allowing students to make observations multiple times helps them notice detail and ask investigative questions based on their own observations of a habitat. By systematically collecting data over time at the same site, students can begin to see patterns.

Breaking a large area into parts can help students consider different aspects of a larger ecosystem. Students need multiple observation sessions outdoors in order to pose meaningful questions. Students could spend multiple sessions observing a large study area, first noting their overall observations, then focusing on looking up, looking down, and looking in the middle. Finally, students can select a much smaller study area for their focused observation.

Lesson

Focus

1. Write the investigative question on the board: "What plants and animals use the school yard habitat?" Discuss strategies for observing—using four of the five senses (sight, hearing, touch, smell) and recording observations (drawing, using numbers, labeled diagrams writing). Hold up an object (e.g., pinecone, leaf, twig, rock) and ask students to describe its physical properties and characteristics. To prompt student thinking you might model drawing and/or writing observations as you ask:
    - What does it look like? (e.g., size, shape, color)
    - What does it feel like? (e.g. texture, temperature)
    - What does it smell like?
    - What does it sound like?

Large Study Area

Explore

2. Divide the class into pairs before going outside. Students spend multiple lesson sessions journaling observations. Students can record measurements. They can use paint chips to name colors they observe in nature. Providing a wide range of green paint chips for example helps to expand students' color vocabulary beyond "green." Below are sentence starters that will help students generate questions about the system (Fulwiler, 2007).
    - I am curious about . . .
    - It surprised me that . . .
    - I wonder how this part effects another part of the system . . .
    - Questions I could investigate are . . .

    Day 1: Overall Observations. Students record general observations and questions.

    Day 2: Looking Up. Students look up (above eye level) and record observations and questions.

    Day 3: Looking Down. Students look down (to the ground) and record observations and questions.

    Day 4: Looking in the Middle. Students look at eye level and record observations and questions.

Reflect

3. After each observation session ask students to share their findings and questions.
4. Categorize the questions students pose (descriptive, comparative, correlative, essential, why, researchable).

Type of Question	Examples
Book/Internet Research	What is the name of this tree or shrub? How tall does this tree grow? Where does this tree grow?
Essential-Life Pondering, Always Wonder	How do trees alter climate?
Descriptive	What do twigs look like in winter? What plants live on this tree? What animals use this tree for their habitat? How does this tree produce seeds?
Comparative	Which type (species of tree) grows the fastest? Are deciduous or broadleaf evergreen leaves stronger?
Correlative	How is tree fall leaf color related to the number of sunny days in fall? How is hot weather related to disease in pine trees?
Why Questions	Why are there deciduous and evergreen trees?

Special Study Area

Explore

5. Divide the class into pairs and give each pair a hula hoop and yard stick.
6. Students select a study area and place the yard stick in the middle of the hula hoop to create transect line and two observation quadrats. Model this set up in the classroom before going outside; show students how to record locations of plants and animals by noting the nearest inch on the yard stick (e.g. there are three acorns, one at 4 inches, one at 15 inches and one at 22 inches).
7. Students record observations using written words/phrases, drawings, labeled diagrams, and numbers to describe the area within the hula hoop, to contrast the two observation quadrats, or to note items along the transect line.
8. Students use field guides to identify plants and animals.

Reflect

9. Students discuss the relationship they have noticed between the large study area and smaller special study area. Ask students, what similarities and differences did you notice?
10. Students formulate two descriptive questions and two comparative questions about the larger study site based upon their observations.
11. Ask students to reflect on the investigative question by writing or discussing, "What plants and animals use the school yard habitat?"

Assessment

Review students' observations for a range of representational forms including numbers, words, labeled diagrams, and drawings. Descriptions might include size, shape, color texture, or smell. As you review student work you can look for

- drawings fill the notebook page
- small objects/organisms are enlarged
- drawings are detailed
- parts of an organism/object are labeled
- color is added as appropriate
- drawings have captions or titles and note the date and place recorded

In addition, in discussion with students as they observe, you can assess their insights and what they reflect about the quality of the observations.

5th grade students at Arlington Elementary School in Tacoma, Washington recorded counts of the animals in Oak Tree Park and then generated questions based on their observations:

What is the most occurring plant at Oak Tree Park?

What are the life styles of the birds at Oak Tree Park?

What is the lifecycle of each species?

What are the eatable plants?

What mammals (not birds) do we see at Oak Tree Park in the spring?

How big is Oak Tree Park?

How many different kinds of trees are there?

What the most common tree?

What part of the forest do most birds live in during the spring time?

Why is Oak Tree Park a good habitat for plants and animals?

What kind of bird is not commonly seen in Oak Tree Park?

Is there water at the park during spring?

How many different animals live in the forest?

What is the most common plant you see at Oak Tree Park?

How many different types of birds are in Oak Tree Park?

How many different types of ants are there in Oak Tree Park?

What is the least common bird you see at Oak Tree Park?

How many total square miles is Oak Tree Park?

What kind of bird do we see in Oak Tree Park?

How many different species of plants are in Oak Tree Park.

Educator Insights

Below are insights shared by pre-service teachers who conducted the special study area investigation. The insights are accompanied by comments about their observations.

"We measured the circumference of this tree and discovered the circumference is equal to our height. We were really surprised; it looks so different in a circle."

Quantitative observations were used; numbers describe the physical characteristics of a tree and demonstrate understanding of comparative measurement by comparing human height to tree circumference.

"We've seen the effects of time in our space; things fly in and out of our space and the amount of shade in our space has decreased."

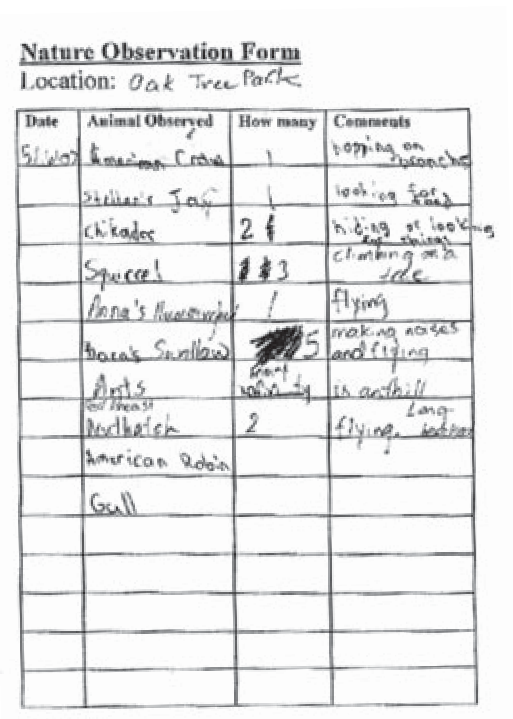
This observation demonstrated awareness that places are not static, but instead are constantly changing by citing two pieces of evidence ("things fly in and out" and amount of shade) to support a claim that time effects what is observed.

"What is this—pollen or a seed? What is this tree that is dropping berries on us?"

By posing questions, pre-service teachers demonstrated a desire to identify the objects they observed. By making detailed observations they could later conduct research to identify the object.

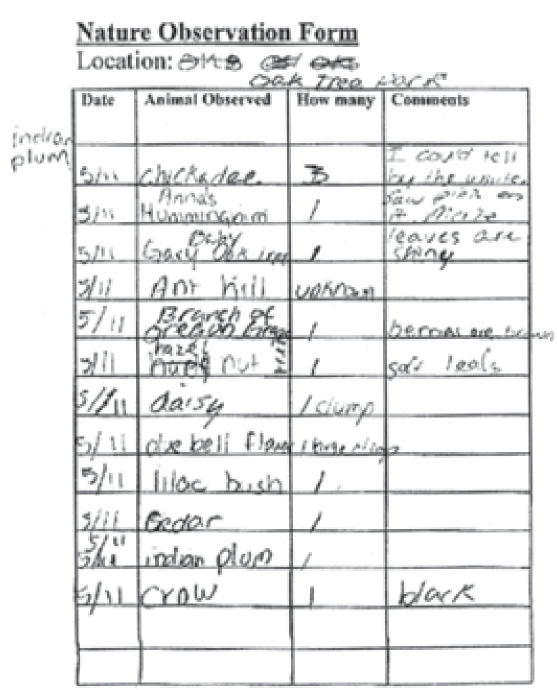
"Look at all the different green colors on this fern. We can't just call them all green."

This careful observation demonstrated attention to nuanced color differences, rather than just labeling an entire plant as green. They recognized a need for a larger color vocabulary to make accurate descriptions.



Nature Observation Form
Location: Oak Tree Park

Date	Animal Observed	How many	Comments
5/[illegible]	American Crow	1	hopping on branches
	Steller's Jay	1	looking for food
	Chikadee	2	hiding or looking for things
	Squrrel	3	climbing on a tree
	Anna's Hummingbird	1	flying
	Barn Swallow	5	making noises and flying
	Ants	many	in anthill
	red breast Nuthatch	2	flying. Long [illegible]
	American Robin		
	Gull		



Nature Observation Form
Location: Oak Tree Park

Date	Animal Observed	How many	Comments
5/11	chickadee	3	I could tell by the [illegible]
5/11	Anna's Hummingbird	1	saw [illegible]
5/11	Oaky Gary Oak leaf	1	leaves are shiny
5/11	Ant hill	unknown	
5/11	Branch of green [illegible]	1	berries are brown
5/11	hazel nut	1	soft leafs
5/11	daisy	1 clump	
5/11	blue bell flower	[illegible]	
5/11	lilac bush	1	
5/11	Cedar	1	
5/11	indian plum	1	
5/11	crow	1	black

indian plum

Appendix C: *What is a Problem*? Activity

1. Write or post word *problem* on the board. Ask the students work with partners/small groups to define *problem*.
2. Have students share their definitions, either by writing them on large paper (such as sentence strips) and posting them or by writing them directly on the board.
3. Work with the students to compare the different definitions while discussing the common words/themes present.
4. Ask the students if they have ever solved a problem? Have them explain to a neighbor the problem they solved (briefly).
5. Discuss how scientists and engineers also solve problems. However, they define problem in a different way (Post and share this definition):

   A problem is a *challenge* that can be solved through the design process (which is a series of steps used to define and solve a problem).
6. Compare the definition with the student definitions. Discuss as needed.
7. Explain that the students are actually going through the design process, called Project-Based Learning. Then, work with the students to brainstorm a list of possible problems that engineers and/or scientists (and even students) might use the design process to solve. For example:
   - Building a bridge
   - Reducing a certain type of pollution in a stream
   - Constructing a more aerodynamic car
   - Attracting birds to a site
   - Reducing erosion
   - Increasing the production of a garden
   - Reducing animal damage on crops
   - Getting rid of (or preventing the growth of) non-native and/or invasive plants
   - Determining the population and/or distribution of an animal population
   - Constructing a new soccer field that will not flood
8. Conclude by revisiting the definition of *problem* (keeping it posted for the duration of the Project-Based Learning Model process) and reminding the students that they will be defining and solving a problem with their teams as they continue to work through the Project-Based Learning Model.

Appendix D: *Change Over Time* Activity

Student Instructions for Creating a Change Over Time Prediction Graph

If you were to watch a time-lapse video related to the problem you intend to solve, what would change over time? Would something increase or decrease? To understand how the problem might impact other parts of the ecosystem, you must first determine how the problem will change over a period of time. To predict these changes, you can create a Change Over Time Prediction Graph:

1) Identify the part or characteristic of the problem (within the ecosystem) that you think is increasing (growing) or decreasing (shrinking) over time.

   Examples:
   - the population (number) of invasive species plants in a location
   - the number of students who play basketball during recess
   - the diversity of birds that visit a birdfeeder
   - the amount of garbage that gets dumped into a creek

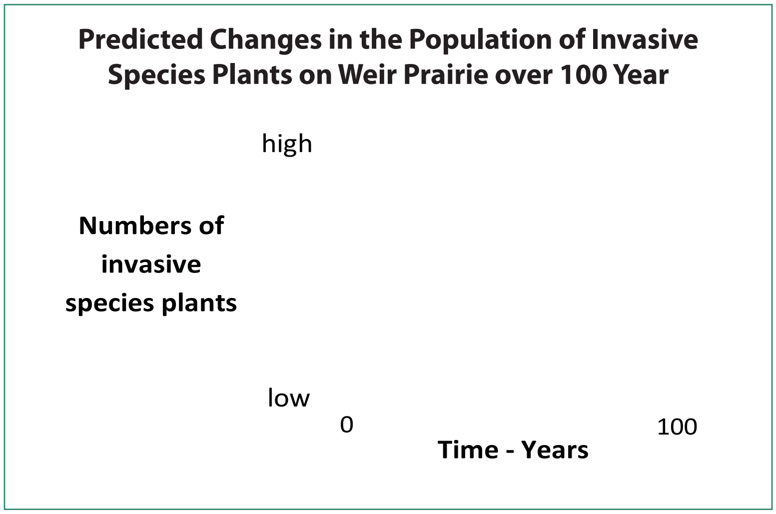
2) Work with your team and/or teacher to determine the length of time you will use as you graph the predicted changes within the ecosystem (1 year, 10 years, 100 years…).

3) Then, on your paper, write a title for your graph. Be as specific as possible, and be sure to include the item/characteristic you think will change (what you are graphing), the location and the length of time.

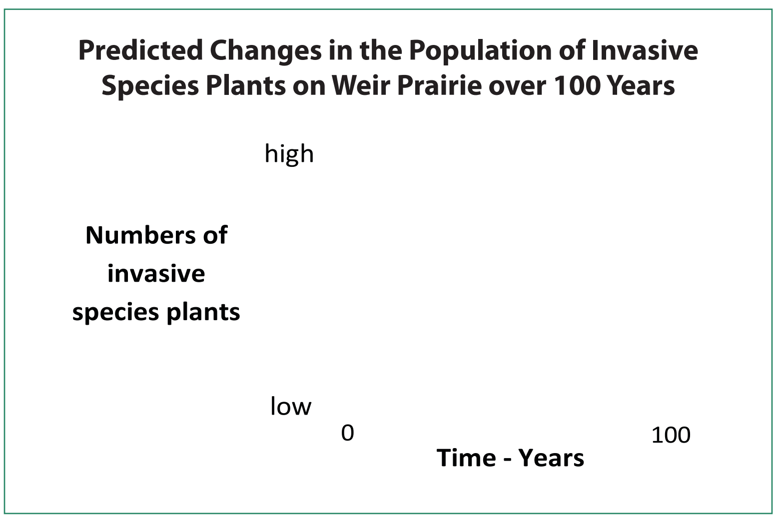
   For example, if you are predicting the change in the population of invasive species plants in a particular location, your title could be: ***Predicted Changes in the Population of Invasive Species Plants on Weir Prairie over 100 Years.***

4) Draw an L-shaped graph and label the Y (vertical) axis with what you're graphing (such as *Numbers of Invasive Species Plants).* At the top of the line, label it 'high' or 'many' (or whatever fits your example). At the bottom of the line, of the line, label it 'low' or 'none' (or whatever fits your example).

5) Then, label the X (horizontal) axis with the word 'Time', a dash and a clarification word such as 'Days' or 'Years.' Then add the numbers, such as 0 years on the left and 100 years on the right end of the line.



6) You are now ready to create your graph, communicating what you think will happen over time. Draw a line starting at 0 on the Time axis that shows how you think the item/characteristic of the ecosystem will change. Will it increase in number? Decrease in number? Fluctuate?



7) Once you have completed your graph, discuss the following with your team or class:
   a. What do you predict will happen over time: In the short-term? In the long term?
   b. What are the potential impacts on the ecosystem as a result of the changes you predict?
   c. How might the item/characteristic of the ecosystem change if you DO influence the system (i.e. attempt to solve the problem)?

November 27

It's early. Like, birds-aren't-even-chirping-yet early. But the way the grass crunches under my feet in this frost almost makes 7 a.m. bearable. **Using the GPS device** to tell our group we're exactly 2,912 ft. above sea level definitely makes it worth it. We hike north with our instructor – I announce our exact longitude and latitude – into deep forest. Signs are all around us. Signs, the instructor says, of cougars. We all laugh nervously. Everyone works together.

We collect evidence – cougar evidence – that we'll use in our classroom labs over the next few weeks. We're not only learning how cougars hunt and live and survive, but we're actually using math and science to figure it all out.

Best of all, my work could actually help make a difference for the cougars.