PEI PACIFIC EDUCATION INSTITUTE

FieldDesign
Engineering Design for Field-Based Applications 6-12

Written by
Karen Lippy, Heather Sisson and Kathryn Kurtz - Pacific Education Institute (2019)

FieldDesign: Engineering design for field-based application 6-12

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TABLE OF CONTENTS

Introduction

Introduction to FieldDesign

The environment provides everything humans need: clean air, clean water, healthy food, materials for shelter and much more. Humans are a part of the natural system, humans create systems: community infrastructure, political systems, economic systems, cultures and religions, technological systems, transportation systems, and all human systems impact the natural system. As a part of nature, we must accept responsibility for the impact our systems make. As the underpinning for our ability to live our lives, the environment provides an intrinsically engaging and authentic context for learning.

The Pacific Education Institute (PEI) provides educators with professional learning and instructional materials that demonstrate how to incorporate ecosystem concepts into the teaching of traditional academic subjects like science, math, civics, economics, art, and English language arts. Our method for program delivery is called the FieldSTEM® Model. Environmentally literate students can examine real-world issues, think critically about the relationship between humans and natural systems, and make informed decisions, while at the same time building problem solving and collaboration skills that will prepare them for civic, academic and career success.

Social, economic and environmental issues can illicit deep feelings and long held opinions which come from everyone's experience in life. As educators, creating a safe classroom culture is critical. In these classrooms ideas and thoughts can be expressed so others can learn new perspective or carefully critique the idea. The Common Core State Standards (CCSS) for English Language Arts (ELA) sets out guidelines for listening and speaking that align well with the FieldSTEM model. Educators must take a balanced approach to instruction, respectfully incorporate differing perspectives and points of view, and modeling how to evaluate information with intellectual honesty. Every individual has a bias, including the teacher, for this reason involving the learners in critical evaluation of data, results, models, conclusions, and opinions benefits all learners in the room.

The Pacific Education Institute envisions a scientifically literate citizenry making balanced decisions for sustainable communities. In order to accomplish this, students of all ages must be engaged in meaningful decisions in their communities. FieldSTEM, PEI's model for integrated, career connected, locally-relevant, field-based learning offers a path for teachers, schools and districts to begin to implement programming to prepare all students for post-secondary learning, careers and citizenship. FieldDesign offers a framework for educators to use to meet the Next Generation Science Standard (NGSS) call for increased engineering design by employing language and math skills and an understanding of natural and social systems to implement three-dimensional science outdoors.

The NGSS calls for conceptual shifts regarding how best to teach science. Driving this shift is the idea that performance expectations are the new standard. Performance expectations interweave the three dimensions of science: disciplinary core ideas, cross cutting concepts and the practices of scientific inquiry and engineering design. Teachers who teach to performance expectations engage students in meaningful activities and projects that lead to the students' ability to understand the core ideas at deeper levels because they are applying the content while practicing the process of science and considering how the new knowledge, they are building fits with their previous knowledge of crosscutting concepts. The shifts outlined in NGSS will teach science, applied in real-world settings, to reflect how science is practiced and experienced in the world.

FieldDesign, engineering design for field-based applications, is a meaningful platform to engage students in engineering with a real problem to solve so they are applying their research and analytical skills to understand situations in a deeper way. FieldDesign works in formal and informal settings and allows students to take ownership for their learning, research existing knowledge, design, optimize and implement projects to solve local problems. Students engage in authentic engineering to become educated, empowered citizens of the 21st Century.

For younger students the projects can be guided by a teacher. As students learn the skills needed to conduct science, educators should help them transition to projects they select. A teacher can set boundaries on the type of projects in order to manage the classroom effectively. When students are given choice, they become more active participants in education. If learning is to be valued beyond school, instruction must engage the learner in the processes of building the knowledge and skills. PEI's FieldSTEM model is integrated, career-connected, locally relevant, field-based learning designed to advance science literacy and inspire balanced decision making for a sustainable future. It is a process that encourages student-driven projects in their communities.

FieldDesign, a framework for engineering design outdoors, is a new addition to the FieldSTEM frameworks. It introduces a step by step guide to take the engineering practices and ensure that students incorporate thinking that leads to sustainable communities rather than teaching the practice of engineering disconnected from the systems, social and natural, that it affects. The steps will look like other models, but key additions require students to reflect on the impact to the ecosystems, social systems and stakeholder views.

FieldDesign & Science Notebooks

Why FieldDesign?

Engineering is fundamental to life, a transferrable and globally-applicable practice, superb at developing critical-thinking, and a remarkable platform for problem-solving. The NGSS directs that through education, students should understand the "influence of science, engineering, and technology on society and the natural world." However, while there is an array of engineering design curricula, none focuses on the role engineering design plays in field-based work with the requirement that students consider the ecological impact of the work they are doing. PEI believes that students need to know about the outdoor, field-based engineering, that is taking place every day, especially as it relates to natural resource and land management, environmental conservation, energy and water systems and agriculture. By learning about engineering design in these sectors, students can connect with their communities, industries and environment, and more fully explore NGSS' recommended considerations, such as: "All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, on the health of people and the natural environment." To really understand this concept, education must move beyond the textbook and the four walls of a classroom, into the field. And FieldDesign is a framework to help educators do this. Through FieldDesign, educators can complete projects such as: designing, building, and testing the effectiveness of Remotely Operated Vehicles (ROVs) to collect water and plant/animal samples, as part of lessons on invasive species or water quality, engineering a solution to a school yard erosion problem to ensure clean water for salmon in their local creek, working with a potato farmer so students can learn about and design solutions to agriculture threats like aphids. Regardless of the issue to be addressed, using FieldDesign, students can engineer and test unique tools that address problems and work to minimize the impact on the environment—powerful learning for students.

Why Science (FieldSTEM) Notebooks?

PEI promotes FieldSTEM: a model of instruction where traditional content areas are integrated to help students apply their learning in their communities. FieldSTEM notebooks are an instructional tool where students' ELA and math skills are utilized in service of developing student understanding about complex social and ecological questions, problems, issues and opportunities. FieldSTEM notebooks have many benefits. They provide a space for teachers and student to track students' thinking and practices - preparing them to be a part of the 21st century workforce, they provide opportunities to increase collaborative communication skills, and provide a vehicle for differentiated instruction.

To help develop globally competitive students, FieldSTEM notebooks provide a place for students to record observations and reflect on the evidence from their field investigations. Notebooks encourage active learning and provide opportunities for students to pursue their own interests and tackle authentic problems (Hargrove & Nesbit, 2003; Gilbert & Kotelman, 2005). With lessons that bridge relevant content this evidence can be used to engage students in collaborative inquiry as a way of learning content, connecting students' thinking and experiences with concepts, and providing opportunities to challenge students, to push them further. Educators must resist the temptation to provide pre-made scaffolds, worksheets, data chart, etc. for students and instead encourage students to embrace their need to learn and grow in their skills. Students will learn to develop effective tables for data collection only if they are allowed to struggle with the number of rows and columns and how to label them. Ultimately, opportunities like these provide students with the skills to think critically and make informed decisions.

A FieldSTEM notebook becomes real evidence of student learning and thinking, and a tool to shape future productive citizens. FieldSTEM notebooks can promote communication between students, teachers and parents or guardians by providing evidence of a student's conceptual understanding and personal reflections providing evidence for student-driven parent conferences where both student and parents or guardians are engaged with the material. It becomes a way of capturing common and individual experiences on paper where they won't get lost, where they can be referred to as needed to drive discourse. By providing student-friendly sense making tools, rubrics, feedback, scaffolding and modeling along with release of responsibility – a process where a teacher encourages and supports learners to design and monitor their own learning around classroom goals - this same evidence can be used by students to self-assess their growth in understanding or their capacity for doing. FieldSTEM notebooks expose students' thinking, providing important insights about student understanding and serving as formative assessment tools (Hargrove & Nesbit, 2003; Gilbert & Kotelman, 2005). This concrete record of reflection, assessment, and connections can be viewed and discussed by teachers who can gain an understanding of a students' thought process, sense-making and patterns across a classroom to modify instruction.

Providing opportunities for all students requires instructional strategies that ensure equity of access. Using modeled scaffolds (graphic organizers, writing frames, etc.) in conjunction with a gradual release of responsibility toward learner independence, FieldSTEM notebooks promote the development of ELA and math skills, scientific reasoning and social competency. Abstract concepts in content areas, when connected to hands-on experiences, where evidence is recorded in the FieldSTEM notebook, provide emergent readers and writers with an effective tool that allows them to increase proficiency in accessing FieldSTEM in the world around them by using ELA and math successfully. Notebooks provide a structure and support for differentiated learning, helping all students to achieve (Amaral, Garrison, & Klentschy, 2002; Gilbert & Kotelman, 2005). Strategies to help implement FieldSTEM notebooks can be found in the Appendices.

Why Learning Outdoors?

There is only one planet earth. While it sounds cliché, it is a truth that must be incorporated into our social and economic thinking. When social and economic systems are designed without thought to the effect those systems will have on the ecosystem, we do ourselves a disservice. The 2003 assessment completed by the World Resources institute says "Human well-being and progress toward sustainable development are vitally dependent upon improving the management of Earth's ecosystems to ensure their conservation and sustainable use. But while demands for ecosystem services such as food and clean water are growing, human actions are at the same time diminishing the capability of many ecosystems to meet these demands. Sound policy and management interventions can often reverse ecosystem degradation and enhance the contributions of ecosystems to human well-being but knowing when and how to intervene requires substantial understanding of both the ecological and the social systems involved."

Engineering design is the process we use to define problems, design solutions and optimize those solutions. In the National Research Council's, A Framework for K-12 Science Education (2102 p11-12) the term engineering is used "in a very broad sense to mean any engagement in a systematic practice of design to achieve solutions to particular human problems." Our economies are heavily tied to engineering design innovation. Materials used for innovations come from the earth and by using them, we affect the earth. If we hope to live in sustainable communities, we must include instruction about the natural systems from which our technology is built. FieldDesign considers technology in the broad sense similar the Framework for K-12 Science Education which states "we broadly use the term "technology" to include all types of human-made systems and processes—not in the limited sense often used in schools that equates technology with modern computational and communications devices. Technologies result when engineers apply their understanding of the natural world and of human behavior to design ways to satisfy human needs and wants." (NRC 2012, p. 11-12).

In Washington State road construction is an example of humans solving one problem and inadvertently creating another, transportation from one town to another required roads which in many cases blocked salmon passage to spawning grounds. In the building of roads, city, county, and private landowners considered how to move water under the road to prevent damage to the road, culverts were built. They did not consider whether those culverts would allow fish passage. Today, due to collaborative policy making between tribes, the state, and landowners, private landowners such as timber companies are designing culverts for fish passage, replacing those culverts and in some cases re-routing roads for fish. Counties and cities too have begun to address the problem. Our efforts to educate young people in engineering must include a consideration of the ecological impacts of that engineering.

As students increasingly grow up removed from natural spaces, experiences in the outdoors are an important instructional strategy for engaging learners in direct discovery of the world around them. This awareness of their local community can prompt a personal commitment to apply skills and knowledge in pursuit of environmental quality and quality of life. Beginning close to home, learners forge connections with, explore, and understand their immediate surroundings. The sensitivity, knowledge, and skills needed for this local connection provides a base for moving out into larger systems, broader issues, and an expanding understanding of causes, connections, and consequences.

Essential Underpinnings and Assumptions

Education is a broad field and much research has gone into the components of effective instruction. There are key foundations to effective instruction and PEI strives to embed them into our practices such as formative assessment and sensemaking for the purpose of tracking student growth and improving instructional practice. At the same time, we are mindful that current work around justice, diversity, equity and inclusion is shedding light on practices that may not show up in existing research, and which may be critical implications for many learners. Some of the practices with which FieldDesign is centered include:
1) equitable access to culturally relevant instruction, 2) integrated learning, 3) learning through the lens of locally relevant context, 4) learning that is student-centered and progressestoward student-directed as students develop their skills, 5) learning that is connected to local job opportunities and important community roles, where students interact with people from the community in those jobs and roles, and that 6) learning takes place outdoors, where ecological impacts are considered as a critical component for community decision making. We believe all students have the right to equitable, integrated, career connected, locally relevant, field-based learning - so they understand the interconnectedness of systems and can make decisions to support sustainable communities.

FieldDesign in the Classroom

FieldDesign includes components of both inquiry and engineering design. When planning how to develop FieldDesign skills, attention is paid to student capabilities in both inquiry and engineering design. Educators and students can begin their projects in one of three ways.

1. **Facilitator-selected FieldDesign:** An educator pre-selects a project, defines the problem, and facilitates the students through the process.
2. **Guided FieldDesign project:** An educator pre-selects a topic. The students work as a class with the facilitator to define a problem within the context of the topic they will all address. The educator leads a guided FieldDesign process with the students.
3. **Student-directed FieldDesign project:** An educator pre-selects a topic. Students individually or in small groups define a problem relevant to that topic and design a solution. For example, if the topic is stream health, one team may design a way to prevent erosion from entering the stream, another may focus on reducing nitrogen flow to the stream, another may reduce an invasive organism, etc. Educators act in the capacity of the facilitator and learn along with students. (Student-directed FieldDesign is fully covered in the secondary version of FieldDesign, this guide will focus on the first two methods of implementation.)

Generally primary teachers would start with a facilitator-selected FieldDesign project to provide structure for young learners. As students move into intermediate grades, teachers are encouraged to transition toward a guided FieldDesign project so that by 6th grade, students are prepared to undertake student- directed FieldDesign. Students in upper intermediate grades who have had little experience with the engineering design process should start with a guided FieldDesign project.

Engaging Students in an Engineering Design Project

There are many opportunities to engage students in authentic FieldDesign. If there is access to a local park or natural area or a site on the school campus, a visit to the site can be the starting point. Have student record their observations and questions in their FieldSTEM notebook. As the students explore the site and begin to investigate situations or phenomenon they encounter, encourage them to focus on what they observed and any questions they have about what they encountered. During a follow up class discussion, have students compile the questions and group them to determine phenomena that can be explored.

When students hear the word problem , most assume something is wrong. A problem is often defined in dictionaries as a situation in which something is at risk. Adults describe many things, including car repairs, lost keys, or injuries, as problems that need effort to be “fixed.” Often associated with a negative, it is no wonder students make that assumption!

In Engineering Design, a problem is a challenge solved through a series of steps used to design a solution. It can be solved with a solution or multiple solutions, but it has a less negative connotation. Engineering design uses a problem to frame the purpose or reason for the project students engage in. Students come to understand that a situation that people want to change or create can be approached as a problem to solve.

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What is the role of Phenomena in FieldDesign?

The term phenomena is used nationally in science education to refer to surprising, puzzling experiences that may be inexplicable, given a student's prior knowledge. Other terms that have been used to describe this idea in the education sector include "disequilibrium", "a discrepant event", and sometimes more generally as "engagement". Phenomena can serve a student in many ways; it can awaken their curiosity to motivate them to understand events, predict and prepare for events, answer questions or help them solve problems. With any instruction, a phenomenon can anchor the topic of instruction by supplying students' experience and thinking toward the challenge of explaining or solving a problem. The purpose of the anchoring phenomenon is to incite curiosity that will motivate the learner as they work toward those explanations and toward implementing solutions. When the anchoring phenomenon is used in concert with formative assessment, an educator has powerful tools to focus learning on student-centered learning.

PEI'S FIELD DESIGN OVERVIEW

STEPS

1 Identify a situation, determine and define a problem
Students use scientific information about a situation or phenomenon to define a locally relevant, field-based problem and describe a desired change. The problem is one that can be solved with the development of a new or improved object, tool, process or system.

2 Research the problem, describe the ecosystem and identify key stakeholders
Students describe the problem in the context of the local ecosystem, social system and understanding of stakeholders and then determine the projects' criteria for success and any constraints that need to be acknowledged.

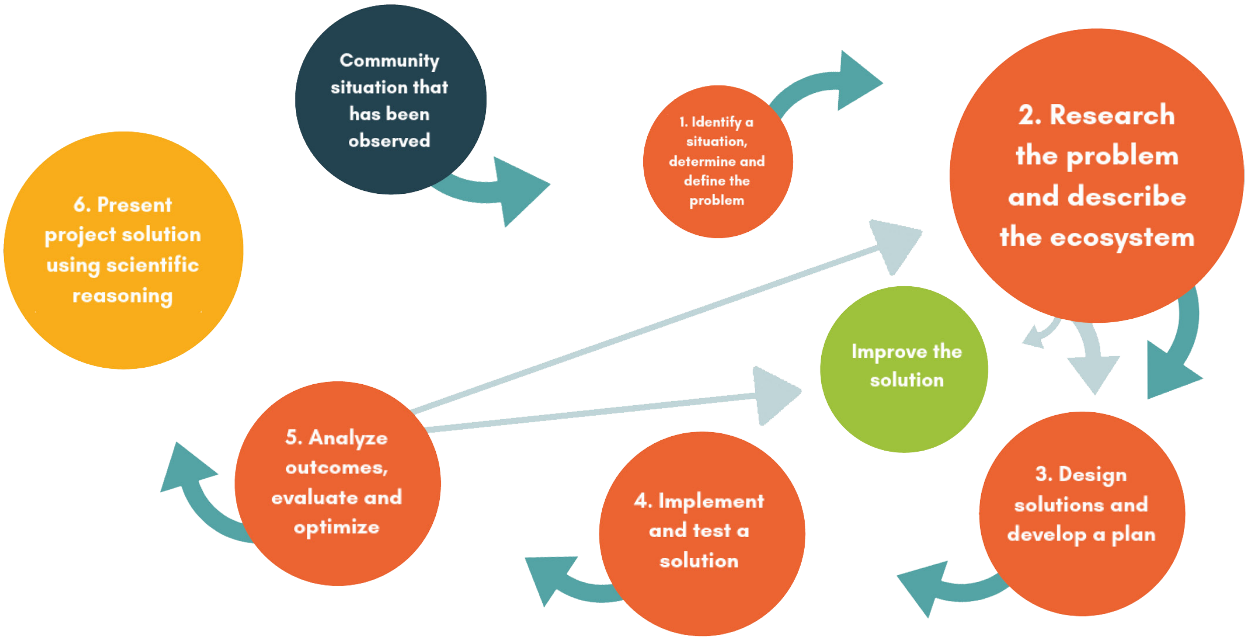
3 Design solutions and develop a plan
Students plan possible design solutions and develop a plan using models to communicate intentions.

4 Implement and test the solution
Students execute their plan based on their research and design in an attempt to solve the problem.

5 Analyzing outcomes, evaluate and optimize
Students make recommendations on how to optimize the results they attained.

6 Present final solution using scientific reasoning
Students give an active and meaningful presentation of their results to their community.

IDENTIFY A SITUATION,
DETERMINE AND DEFINE THE PROBLEM



STEP 1

NGSS Information: Science and Engineering Practices

- Asking questions (Science) and defining problems (Engineering)
- Developing and using models
- Planning and carrying out investigations
- Constructing explanations (Science) and designing solutions (Engineering)
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

Science and Engineering Practice: Defining Problems

Examples of outdoor phenomena - based problems:

- plant damage/disease
- extreme weather events
- ocean acidification
- phenology
- stormwater runoff
- accelerated erosion
- increasing greenhouse gases
- generating enough energy
- invasive species
- rising sea levels

When students hear the word problem, most assume something is wrong. A problem is often defined in dictionaries as a situation in which something is at risk. Adults describe many things, including needed car repairs, lost keys, or injuries, as problems that need effort to be "fixed." Often associated with a negative, it's no wonder students make that assumption!

In Engineering Design, however, the problem is a challenge solved through a series of steps used to design a solution. It can still be fixed with a solution or multiple solutions, but it has a less negative connotation. Engineering Design uses a problem to frame the purpose or reason for the project students engage in. Students come to understand that a situation people want to change or create can be approached as a problem to solve.

At the beginning of the problem exploration, have the students visit a site and begin their observations and questions in their science notebook. If a graphic organizer is needed, the O.W.L. chart can be a helpful tool. An O.W.L. chart: Observations, Wondering and Learnings, is a great way to organize student thinking.

Students can record their observations and wonderings (questions) without too much prompting. If they need prompting for observations, ask them to:

- identify living and non-living things
- ways that humans have changed the area
- describe the topography
- use their senses to gather information

In the beginning they may not have much to add to "learnings", new information that they acquire during the process.

O.W.L.: Human Impacts on Our School Grounds		
Observations	**Wonderings**	**Learnings**

The process of continually making observations, asking questions, and reflecting on newly gained knowledge is important for learners. Throughout Step 1, students revisit the field site with their original O.W.L. chart to update previous observations and wonderings by recording their new thinking. An O.W.L. chart therefore becomes a visual model that demonstrates a students' growth over the course of the project.

It is important that young students understand there are constraints to what they know. While outdoors there will often be complex interactions that cannot be easily observed which may affect the scenario. For example, elementary students will not understand the interactions of molecules occurring at the site, when this level of understanding is incorporated, a learner will have different solutions to the problem that can't be understood at the macro level.

For a Guided FieldDesign Project:

If the phenomena-based problem is already identified, the facilitator works with students to share the phenomena they will study and asks questions to engage them in considering the problems they might choose to solve. The phenomena-based problem can be chosen using facilitator-created criteria such as:

- comfort level with the number of unique team investigations
- time available to dedicate to the project resources
- topics for learning goals
- other systemic constraints

The facilitator keeps the focus on the pre-identified problem or expands it by guiding students to explore additional problems within the topic. The facilitator introduces phenomena in a way that the students
grapple with it as they begin to understand how it is connected to more problems which may motivate them to engineer solutions tied to those problems.

An O.W.L. chart can also be used as a tool for classroom discussion. Further plans can then be made regarding whether the remaining steps will be carried out as a class, in teams, or other groupings.

For a Student-Directed FieldDesign Project

Students will begin this project by determining and defining the problems related to a topic or context provided by the facilitator. Student teams will outline different problems and the facilitator will lead discussions to expand students' thinking about the problem and potential solutions. Considerable facilitator guidance may be needed to assist students in deeply understanding and focusing the problem and exploring a variety of engineering solutions.

A discussion scaffold or another method of compiling observations, wonders, and what has been/is being learned may be used. Further plans can then be made regarding whether the steps following step1 will be carried out in teams, or other groupings.

TEACHER TIP

Because students own many of the decision-making opportunities within the process of engineering design, we are referring to teachers and mentors as facilitators. Quite often the role of the adult hosting the learning is one of facilitating student learning rather than leading students through a preset progression of learning tasks. The steps of FieldDesign can assist facilitators with understanding the learning progression students will move through and serve as a planning tool for scheduling sessions.

Mr. Gonzalez's 7th Grade Vignette: Guided FieldDesign Project

Mr. Gonzalez's seventh grade class has been learning about matter and energy cycling and ecosystem interactions in a unit titled "Disruptions in Ecosystems." They have been examining some of the ecological challenges that occur when humans change an aspect of an ecosystem. Students begin drifting into deeper global discussions about problems which would require political action as part of the solution, eventually students begin moving to a "we are just kids, adults make the decisions" stance. Gauging that his students feel a need to impact change, he decides to frame their work around human impacts focusing on the Life Science performance expectations in NGSS: MS- LS2-4 "construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations and ecosystems affect populations" and MS-LS2-5, "evaluate competing design solutions for maintaining biodiversity and ecosystem services." Mr. Gonzalez decides to utilize his students' prior knowledge to engage them in the NGSS performance expectations for engineering design (ETS1, 2 and 3) and shifts his focus to the immediate area that students could impact with solutions, if they choose - the school grounds. He hopes to broaden their perspective on the Earth's ecosystems interactions and thinks the motivation students have shared in their last unit will carry forward to this unit.

The class takes an "impact walk" around the school grounds, tasked with noting potential human impact problems that the class could explore while recording observations on individual O.W.L. charts. The school grounds include play fields and stand of trees, bordering a neighborhood of houses. Some students noted litter concentrated in areas around the baseball backdrops, others observe dirt and mud trails being created on grass sports fields where foot traffic is high, and many were drawn to the forested area. They noticed that adjacent to the area of trees was a patch of Scotch broom and scattered blackberry bushes. They also noted the differences in other plants in the various areas. The stand of trees also had dirt trails and litter.

When the class returns to the classroom to discuss their findings and choose a problem, not all students agree which problem to pursue. Mr. Gonzalez quickly realizes he will need to decide whether to require the class come to consensus on one problem, using a vote if necessary, or if he could allow for groups to investigate multiple problems and projects around human impact on school grounds. He realizes that he will want to post the problem(s) so that students will keep work times focused on finding a solution. The group pauses to brainstorm Wonderings while he considers next steps.

TEACHER TIP

In NGSS, engineering exists both as a practice and can be found in performance expectations and as engineering standards arranged into "grade bands." The secondary grade bands are Middle School 6-8 and High School 9-12 for Engineering, Technology, and Applications of Science. Over these bands, in the engineering standards, students progress to more independently choosing problems, analyzing research and models, while balancing multiple factors when deciding on possible solutions without teacher direction. The teacher will still aim student learning toward appropriate performance expectations, granting increasing freedom to students as they design solutions and work to evaluate whether they solve the problem or not.

O.W.L.: Human Impacts on Our School Grounds		
Observations	**Wonderings**	**Learnings**
Litter on baseball field Litter in trees Erosion trails through sports fields where kids walk Erosion trails through the forest Weeds, such as Scotch broom, blackberry and ivy	Why aren't people using trash cans? What kind of litter is being found? School rules say we aren't supposed to go into the trees, but people are making trails and leaving litter there? Are they students or other people? Why do we have a pattern on how people cross the field? And, why don't all people follow the same path across the field? Is there a way to get rid of the weeds? How do weeds impact the school grounds? What animals live in the forest? Who makes decisions about what grows on the school grounds?	

Mr. Gonzalez has decided that the presence of weeds gives the best opportunity for multiple projects that students could research and tie into contacting community collaborators. Although he will allow multiple interest projects to be chosen within this topic, he will lead the class to define the problems within this topic.

If a group cannot choose which problem to use for their project, further research and observations outside may be necessary, even postponing final decisions about choosing a problem until investigations can be conducted to build students' background understanding. If students end up choosing multiple projects within the topic, this would be an example of Student-Directed Design.

Or, as in the vignette above, a facilitator chooses a problem area of focus to continue the pace of the learning. Using examples from above, the facilitator could summarize traffic pattern impacts as a basis for student project choice. Students could tackle trails being created in the grass fields, observing traffic patterns at outdoor line-up times, conduct a study about the sources of litter, or the conditions encouraging the growth of weeds. Students may also be more engaged if they can follow their peers suggested topics.

Ms. Baker's 10th Grade Vignette: Student-Directed FieldDesign Project

Ms. Baker's tenth grade class has been learning about populations in ecosystems in a in a unit titled "Calculating Biodiversity in the Real World." They have been comparing various communities' populations by gathering population data, calculating biodiversity and analyzing mathematical patterns to find carrying capacity. Students were utilizing the school grounds and a neighboring park to collect data. Their field studies were ongoing, and they had noticed problems in both areas. A few students enthusiastically wanted to jump in and fix some of the problems. Ms. Baker decided this was the perfect opportunity to provide students an opportunity to design their own projects to address the problems they had identified. This would also give her the chance to engage them in the NGSS performance expectations for engineering design (ETS1, 2 and 3), while teaching the Life Science performance expectations in NGSS: HS-LS2-2 "Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales" and HS-LS2-6 "Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem."

NEXT GENERATION SCIENCE STANDARDS

HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Ms. Baker knew most of her students had completed a guided FieldDesign project in their ninth-grade science class, so she proposed the students take on student- directed FieldDesign projects. Her students eagerly agreed.

Students were familiar with both the school ground study site and adjacent park, but most had been focused on the task of collecting population data. Ms. Baker had the class return to these study sites to focus on the problems they had been noticing. She had them recording their observations on the O.W.L. charts.

Listening to her students' during the walk, Ms. Baker was impressed with the detail and diversity of her students' observations. They notice everything from the composition of the litter on the school ground, to variance in bird populations in various tree stands, to the variety of algae growing around the park's river. Areas of concern were also identified, such as an outflow pipe dumping into the river, erosion on the banks of the river, vandalism on the school grounds and in the park, and some dead fish washed up on the bank.

When students returned to class, Ms. Baker conducted a class discussion and gathered the students' observations and wonderings on the whiteboard for the class to see.

O.W.L.: Human Impacts on Our School Grounds		
Observations	**Wonderings**	**Learnings**
There is a lot of litter on the school grounds that comes from our lunches. The park has litter mostly from local fast food restaurants. The river has some green and brown algae growing in it. There are more birds in the maple trees than in the firs. The birds in the alder tree are all the same species. Few birds are on the school ground trees, compared to the park. There is an outflow pipe into the river. There is erosion on three sections of the riverbank. There is vandalism and graffiti on the school grounds and the park. There are dead fish on the bank of the river.	Are there enough garbage cans on the school grounds? Are there enough garbage cans in the park? Are the garbage cans placed correctly? What animal species are affected by litter? What is the difference between the brown and the green algae? What causes algae to grow in a river? What other organisms are affected by algae growth in the river? What kind of birds live here? How do different birds use different trees? What kind of food do the birds here eat? What is coming out of the outflow pipe? Is it legal to have that outflow pipe in the river? What are the effects of erosion on fish populations? What is causing the riverbank erosion? When does vandalism occur in the park and school grounds? What kind of dead fish are they? What kinds of fish live in the river? What killed the fish?	

It was clear during the discussion to both the class and Ms. Baker that there was a wide variety of problems and many questions. Ms. Baker decided at this point to let students have some time to think about which problem they were most interested in addressing for their FieldDesign project.

She also announced that the next day students would be allowed to form groups of three or four to work together for the rest of the project. The class had already shown skill in forming productive, collaborative teams in their earlier field investigation activities.

The next class period, Ms. Baker assigned each of the groups a Researching the Problem worksheet to complete. She modeled the first few prompts. This worksheet was to be turned in for her review at the end of the class period and would be returned to the team the next day, after Ms. Baker had a chance to review each team's ideas and provide feedback.

TEACHER TIPS

- Facilitator review and feedback are critical in Student-Directed Field Design. Each step should be carefully checked to make sure students are on the right track and not missing a critical component. The feedback should be primarily in the form of questions, prompting students to think about something they are missing or a potential impact of their action.

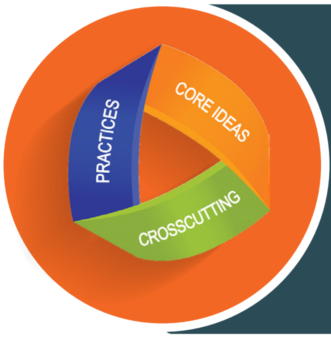
- Each team should have a tool to organize their work, such as a binder to keep all the worksheets and other artifacts of their work. It also provides evidence that can be used as a summative assessment of the students' project.

2 STEP

RESEARCH THE PROBLEM,

DESCRIBE THE ECOSYSTEM AND IDENTIFY KEY STAKEHOLDERS

STEP 2



NGSS INFORMATION: SCIENCE AND ENGINEERING PRACTICES

- Asking questions (Science) and defining problems (Engineering)
- Planning and carrying out investigations
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

In step 2, groups of students will need to determine what they already know as well as what they still need to know. They can refer to their O.W.L. Charts to consider what they learned or will continue to learn during their site visit and can consider the prompts in the Researching the Problem document to guide their note taking. Students generate a list of information and resources they will need to gather before designing solutions.

The facilitator acts as encourager, allowing students to take charge of their learning and equipping them with tools and resources to support success. Researching (CCSS reading for information standards), collaboration (CCSS speaking and listening, comprehension and collaboration standards) and questioning skills can be helpful in this step. The facilitator offers guidance as students search out information, address reliability of sources, refine their questions, and connect with experts if possible. All practices that “professional scientists and engineers” use.

With a problem identified, the class focuses on determining what more they can learn about the situation and how it came to be. It isn’t time yet for students to think about potential solutions since clearly defining the problem, considering criteria, constraints, stakeholders, and the ecosystem are important prior steps. If students begin to propose potential solutions as they research factors impacting the problem, they can be recorded in the “My Notes” section of the Research the Problem document, to be used later. Use the suggested or similar prompts to guide students as they gain a deeper understanding of the problem.

Redirecting the focus on research for this phase is critical. If this step is skipped, the lack of relevant background information and thinking will interrupt students’ viable solution generation later as they have to rework solutions because they did not consider constraints adequately.

Mr. Gonzalez’s 7th Grade Vignette: Guided FieldDesign Project

Mr. Gonzalez begins modeling use of the Researching the Problem prompts for students to record their discussions and to scaffold how they will keep notes on their progress later independently. He decides to copy this resource and pass it out the next day, so he can begin releasing responsibility to his students for brainstorming what they need to know, where they can find the information, and taking notes on what they discover.

Researching the Problem

1. **In one sentence, describe the problem you're planning to solve:**
   How can we reduce the amount of invasive plants on our school grounds?

2. **Why is this problem important? What will happen if no changes occur?**
   Invasive plants grow aggressively and crowd out the native species that live in an area. Also, many invasive species are not edible, and some can even kill other species directly.

3. **What I already know that may help:**
   Scotch broom, non-native blackberry and English Ivy are invasive species. These invasive species are not useful habitat for most creatures, though birds and animals can eat blackberries. English Ivy can kill trees. Invasive species easily spread to other areas. Property owners are responsible for preventing the spread of weeds.

4. **What I need to know before starting:**
   What plants might we put in place so that the habitat is useful for animals that live in the area, are the soil conditions right for those plants?

5. **Where I might find information (books, websites, experts):**
   Native Plant growing books from local garden stores or the library, Master Gardeners in the area

   My notes (cite your sources):

After the students complete their research, their understanding of the problem may have changed, and a new problem now needs to be defined.

1. **The problem (complete sentence):**
2. **Criteria (goals): increased types of animals and increased populations of animals**
3. **Constraints (limitations):** School district facility approval, 2 months to install before school is out, we only have $300 from the PTA to spend
4. **What I know now that may help:** There are several native plants that can grow in the area that we have, and they should attract animals.

After initial researching and deliberating as a class, the seventh-grade class is learning about invasive species, their impact on ecosystems, and how humans can encourage or discourage their growth. Small groups of students have chosen different subtopics they needed to know more about to approach the problem, decided on where to find the answers, researched and summarized what they learned on their Researching the Problem sheets, and presented findings to the class. They have learned that when the playfields were constructed, the Scotch broom and non-native blackberries sprung up in the area next to the trees. They also found English ivy growing on the trees within the forest. They found out that the school ground maintenance department only has resources to mow the existing fields. They also met some of the neighbors who were upset that there was so much Scotch broom, since it contributed to their allergies. The neighbors also liked to take evening walks in the trees to look for birds and wildlife. Student discussions leaned toward feeling helpless with this problem.

"Mr. Gonzalez, if the school grounds maintenance people can't get rid of the weeds, what are we supposed to do?" a dejected boy, Brian, asks.

Mr. Gonzalez replies, "Well, are there any other adults we can think of who would be interested in helping us think through the control of invasive species, even if the maintenance people can't?"

The class goes quiet for a while, then Brian shares, "My grandma is a Master Gardener. She took a class about invasive species. Maybe she knows someone who can help?"

"Good thinking," Mr. Gonzalez responds. "Does anyone else have family members who gardens or landscapes? They may have ideas of organizations or clubs who would be interested in helping you. We call those interested people, 'stakeholders.' It's important we look at many sides if we want to solve this problem. They may have already worked through some barriers we haven't thought of yet or have experiences that can help."

Three other students offer to contact family members that evening and share the information they collect. Mr. Gonzalez explains that having questions ready may help, offers copies of the Stakeholder Research page to students, and asks students to generate three questions and record them in their science notebooks. The class works on completing each student's Stakeholder Research copy together with the information they received from the school district, and answer the questions together based on what they know. They will return to add more information based on what the four students' family members share from the evening's phone calls on a new Stakeholder Research sheet.

Stakeholder Research

Stakeholder points of view are important to understand before planning solutions.

Stakeholder name (individual, organization, business, agency):
School District Facilities and Maintenance

Stakeholder website:

Contact phone number/email: Office 555-211-1357

Contact name: D. Williams, Director

How is this stakeholder connected to the problem?
The school district is responsible for the maintenance of all school grounds.

Is the stakeholder aware of the problem? If so, what are their opinions about it?
No. When we contacted Mr. Williams, he was not aware of the expanse of weeds on the site. He was concerned and sent a staff member to look over the site. They agree that weeds are a problem, especially the Scotch broom and ivy. They are unsure what action can be taken with their limited resources.

If the stakeholder owns land where the project would take place:

- **How do they currently use the land?**
  The area with the trees is part of the school grounds, but not used for any formal activities.
- **Does that use of the land impact the problem? If so, how?**
  Since no one uses that area, it is ignored.
- **Are they trying to be environmentally-friendly? Explain.**
  They do not used pesticides on school grounds. This is not an option for them to address the problem.
- **Are there laws that affect the way the stakeholder can use the land?**
  There are laws making the school district responsible to control the spread of weeds. There is also a law and policy prohibiting the use of pesticides.
- **Are there any culturally or familial connections that ties the stakeholder to the land?**

How could the problem affect the stakeholder now and in the future?
The weeds already are spreading into the playfield area. This will soon affect the use of the field. Also, there is ivy growing on the trees in the forest. Eventually, this will kill trees and create a dangerous situation when they fall. And, the neighbors will be unhappy, if they have more allergy problems or cannot enjoy the natural area because of the weeds.

How could the stakeholder contribute to the problem?

How could they be part of the solution?
We could ask if they would be willing to meet with the local Noxious Weed Board to learn about the problem and explore possible solutions.

Would the stakeholder like to play a role in this project? If yes, what role?
(For example, speaking to the class or providing resources) Right now they say they don't have the resources, but are willing to meet with other organizations to look for solutions. They also are willing to review student suggestions and cooperate where possible.

Would the stakeholder be interested, financially, in finding a solution?

Ms. Baker's 10th Grade Vignette: Student-Directed FieldDesign Project

The groups of students in Ms. Baker's class are now formed and identifying what they know about the problem, what more they need to know, and where to find it. They have researched and summarized what they have learned on their "Researching the Problem" sheets. Ms. Baker has reviewed the sheets and provided feedback to each group.

Ms. Baker felt it was important to have a whole class discussion. While students were independently working in their groups, they also needed an opportunity to network with other groups, since there were likely to be overlapping ideas, struggles and knowledge of resources.

Ms. Baker also dedicated a section of white board for groups to post questions they were struggling with and information they felt would be useful to the whole class. This tool would be used to encourage collaborative problem solving.

Questions and Requests for Help	Information to Share

Ms. Baker holds a brief discussion of who might be stakeholders in the projects the students are considering. She assigns each group to complete a Stakeholder Research sheet for each of their stakeholders. These sheets will be turned in for review and feedback.

TEACHER TIP

Once students have researched the problem more deeply, they can participate in an optional activity where they consider the problem through the lens of another crosscutting concept. Students consider the impacts of the problem on the bigger system. For example, equipped with new information related to stability and change, the students could 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 it. Systems thinking is about seeing the world as whole and interconnected It looks at how parts of a system can affect changes in other parts over time.

Stakeholder Research

Stakeholder points of view are important to understand before planning solutions.

Stakeholder name (individual, organization, business, agency):
Parks Department

Stakeholder website:

Contact name: D. McNair, River Park Director

Contact phone number/email: 555-211-2222

How is this stakeholder connected to the problem?
The Parks Department is responsible for the River Park. The park is owned by the city, but all operations and decisions are directed by the Parks Department Board and staff.

Is the stakeholder aware of the problem?
If so, what are their opinions about it?
No. When we contacted Ms. McNair, she said that as far as she knew the river was fine. Neither the park staff nor the public had reported any problems.

If the stakeholder owns land where the project would take place:

- **How do they currently use the land?**
  The park is public and provides recreational and outdoor activities to many groups and individuals. Families visit the park year-round, enjoying the picnic area, swimming, floating and fishing in the river (no boats allowed), and walking with their dogs. School groups also frequent the site for both recreational and learning activities.
- **Does that use of the land impact the problem? If so, how?**
  The algae growth in the river could be related to the activities, but it is not known for sure at this time. There is a septic system at the park. There is run-off from a parking area that has a pipe diverting runoff to the stream. There are several areas where foot traffic appears to have eroded the banks. There is dog poop in some areas. There is also a lush green lawn that is likely fertilized. When Ms. McNair was asked, she was not sure if they used fertilizers in that park.
- **Are they trying to be environmentally-friendly? Explain.**
  The parks department follows all laws related to their land use. They are working on a new management plan to improve their practices related to the land.
- **Are there laws that affect the way the stakeholder can use the land?**
  There are city and state laws regarding septic function, parking lot runoff and use of pesticides/fertilizers. However, this park was built many years ago and the park director agreed that there were some things that needed to be addressed to make sure they were still in compliance under the new laws.
- **Are there any culturally or familial connections that ties the stakeholder to the land?**
  No, they are not an individual or family group. But this park has been around for generations and the users have a strong sense of ownership and care a lot about being able to keep using the park.

How could the problem affect the stakeholder now and in the future?
The algae blooms in the river are a sign that something is getting in the water that is providing nutrients. This could be a septic, fertilizer, or runoff issue, which could also become a public health issue for park users who play in the river. In addition, the presence of dead fish indicate there may be negative effects to other wildlife populations and result in the public not being able to catch fish.

How could the stakeholder contribute to the problem?
The Parks Department is critical in this situation. The algae bloom is likely directly related to one of the activities in the park. The park director was cooperative and agreed to look into the problem. The parks department is responsible for addressing problems and providing solutions.

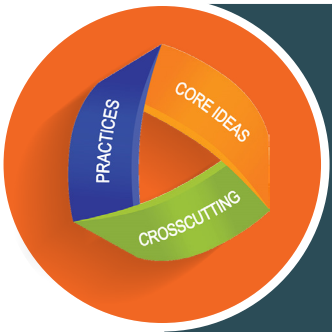
How could they be part of the solution?

Would the stakeholder like to play a role in this project? If yes, what role?
Ms. McNair said she would immediately call the county health department and have the septic system dye tested to make sure it wasn't putting effluent into the river. She also said she would investigate what fertilizers, if any, were being used on the park grounds. She wasn't sure what else she could do with their limited resources, but she was willing to continue to meet and explore other solutions.

Would the stakeholder be interested, financially, in finding a solution?

3
STEP

DESIGN SOLUTIONS AND
DEVELOP A PLAN



NGSS INFORMATION: SCIENCE AND ENGINEERING PRACTICES

- Asking Questions (Science) and Defining Problems (Engineering)
- Developing and Using Models
- Constructing Explanations (Science) and Designing Solutions (Engineering)
- Analyzing and Interpreting Data
- Engaging in Argument from Evidence
- Obtaining, Evaluating, and Communicating Information

Often students identify problems on school grounds that are not new. Knowing the history of the problem, what's already been tried, and the results of that solution can be of great value. These may have been addressed a few years ago and the solution wasn't sustainable.

Students can research and evaluate ideas that others have proposed, and actions previously taken or record original ideas. Using the Solution Analysis document will help scaffold discussions, focus "best plan" argumentation, and eventually narrow plans down to one proposed solution. Students will most likely find multiple solutions to a problem, each with its own set of benefits and consequences.

The following is an example of Amelia and Nevaeh's Solution Analysis and Solutions Comparison table with their original ideas from Mr. Canon's classroom:

Name: Brian, Marcie, Alex Date: 10/2

Solution Analysis

You are ready to brainstorm possible solutions to the problem! Others may have tried to solve this same problem in the past. Research what solutions have been tried. This information may come from your stakeholder research or from new information you have gathered.

You may also have some of your own ideas of possible solutions. Each possible solution will have its own set of positive impacts and negative consequences. To decide the best possible solution to the problem you chose, follow this process with each solution you learned was already tried and those you have developed.

1. **Create a list possible solutions. Write down all the possible solutions you learned about during your research as well as your own ideas:**
   - ~~Remove the Scotch broom ourselves.~~
   - Work with Noxious Weed Board to organize and host a neighborhood work party to remove the Scotch broom.
   - ~~Plant large trees around the Scotch broom and blackberries to shade them out.~~
   - ~~Write a grant to get money to hire people to remove the weeds.~~
   - Remove ivy from the trees ourselves.
   - Cut back only the Scotch broom around the blackberry and advertise free blackberry harvesting.
2. **Narrow your list down. Cross out any ideas that don't seem realistic or do not interest you.** (Keep in mind that just because some projects will require money and/or experts this does not mean the solution is unrealistic. Groups and businesses are often willing to donate materials, their time or funds to help students with projects)
3. **Choose your top 3 solutions. You will start by analyzing only these 3 in order to decide which one you plan to complete.**
4. **Compare solutions using the Solution Comparison Table.**
5. **Choose the best solution for your project based on the Solution Comparison Table and share your choice with your teacher to get approval for your project.**

After comparing and analyzing lists of potential solutions, students move into using the Solution Comparison Table to analyze their group's top possible solutions. This could be done in their science notebooks, distributed as a copy of the table to be taped inside their notebooks, or part of a packet the teacher has created.

SOLUTION COMPARISON TABLE

Possible Solution Summary	**Criteria for success and positive impacts**	**Potential negative consequences**	**Stakeholder thoughts**	**Constraints that may make this difficult**	**Is the plan reasonable?**
Who was/will be involved in the project? What did/will they try? How did/will they go about their solution? When was/will this be? Where was/will this be?	What positive impacts on the environment could come from this solution?	What results of this solution could be harmful?	What might stakeholders like or dislike about this solution?	Consider time, resources, liability, etc.	Rank how likely it could be completed: 1 = low 2 = Medium 3 = High 4 = Certain
1. *Work with Noxious Weed Board to organize and host a neighborhood work party to remove the Scotch broom.*	We would get rid of Scotch broom which could allow native plants to grow and benefit insects and birds.	There is the chance that once removed, more weeds will move in.	It may leave a big messy area that has to be fixed. It would need to be done repeatedly to get rid of the Scotch broom.	It will be hard to get enough people out to do this big a job.	3
2. *Remove ivy from the trees ourselves.*	We would save trees from being killed.	We have to make sure we contain all the ivy we pull so it doesn't spread to new places.	We think the school district would like this.	We need to have tools for cutting and tarps to contain ivy.	4
3. *Cut back only the Scotch broom around the blackberry and advertise free blackberry harvesting.*	This would provide blackberries for people to eat.	People might get scratched picking blackberries.	The neighbors would be happy because they could pick berries. The city might want to get rid of blackberries and not have them encouraged.	We need tools to cut the Scotch broom and gloves to work around the berries.	3

TEACHER TIP

Some students may research and brainstorm solutions at a pace that does not match that of their peers. To ensure all students can record their ideas, plan enough time for students to finish and ensure the students that finish early have a productive activity to engage in allowing slower students time to contribute.

Through this process students gain a perspective that each action has potential reactions, both positive and negative, and that multiple perspectives and factors need to be considered when deciding if a potential solution can be successful.

TEACHER TIP

Some students may research and brainstorm solutions at a pace that does not match that of their peers. To ensure all students can record their ideas, plan enough time for students to finish and ensure the students that finish early have a productive activity to engage in allowing slower students time to contribute.

Mr. Gonzalez's 7th Grade Vignette: Guided FieldDesign Project

"Alright everybody, science partners have all completed their Solution Analysis and narrowed down what they think are the best choices to consider. Now we are going to work on comparing what's left by considering our criteria, constraints, and how likely the solution is to work. After this, we will talk as a class and make our choices for our project. Partners, here is how we are going to work through this..."

Mr. Gonzalez explains the process using the sheet below, which he will photocopy so that students can each have a record in their journals the next day. During the last 15 minutes of class partners share their highest rated solutions and he compiles them into a class data table for consideration the following day.

SOLUTION COMPARISON TABLE

Possible Solution Summary	Criteria for success and positive impacts	Potential negative consequences	Stakeholder thoughts	Constraints that may make this difficult	*Is the plan reasonable?
1. *Work with Noxious Weed Board to organize and host a neighborhood work party to remove the Scotch broom.*	We would get rid of Scotch broom. We would have neighbors who would care more. Healthy plants would have a place to grow. Other wildlife could move into the area. Our presentation to the board would show we care about the ecosystem.	There is the chance that once removed, more weeds will move in. We might not be able to get rid of all the Scotch broom and it just grows back. The bare dirt left might end up being eroded and damaging other areas.	It might make the school district unhappy to have the community do this instead of them. It may leave a big messy area that has to be fixed. The neighbors would be happy that their allergies were better. The students and the neighbors would get to know each other. The Noxious Weed Board would get to educate people.	It will be hard to get enough people out to do this big a job. We can only make 100 copies of flyers in office, so may need to find another way. We need to get the school district's permission.	3

*Rank how likely it could be completed: 1 = low, 2 = Medium, 3 = High, 4 = Certain

Possible Solution Summary	**Criteria for success and positive impacts**	**Potential negative consequences**	**Stakeholder thoughts**	**Constraints that may make this difficult**	***Is the plan reasonable?**
2. *Remove ivy from the trees ourselves.*	We would save trees from being killed. If the ivy was gone, there would be room for native plants and other species.	We need to make sure we get rid of all of the ivy, or it will just grow back. The trees may be ugly or damaged when the ivy is removed. Any ivy that we remove and do not destroy will just root again and grow where we leave it. We could get hurt while cutting the ivy.	We think the school district would like this because the forest will be healthier. The school will be proud of us because we did it ourselves. The neighbors will be happy that the trees won't die.	We need to have tools for cutting. We need tarps to contain ivy and a place to compost or dispose of it. We need permission from the school district. We need permission from our principal. We need to find a time we can do this during the school day.	4
3. *Cut back only the Scotch broom around the blackberry and advertise free blackberry harvesting.*	This would get rid of some of the Scotch broom People would have blackberries to eat.	The Scotch broom will still be there. The blackberries will still be there. People might get scratched picking blackberries. We might get scratched when doing the project. There may be more trails created in the forested area by people walking to the blackberries	Volunteers may not want to fix things that they already worked hard on. People may not want to donate materials. Maybe they did one time before and those kids didn't take care of it?	We need tools to cut the Scotch broom. We need gloves to work around the berries. We need to get school district permission. We need to make sure the school district is ok with more people coming onto the school grounds.	3

*Rank how likely it could be completed: 1 = low, 2 = Medium, 3 = High, 4 = Certain

The final part of Solution Analysis is having students decide on the one plan they would like to develop and defend (argue with evidence) the reasoning behind their decision.

This is a good opportunity for the teacher to gain understanding of the class's thinking and priorities and to give approval (or not) before students begin the work of planning their project.

TEACHER TIP

There are both pros and cons to having groups begin collaborating right away to construct lists of possible solutions together. To ensure introverts are part of the conversation, consider giving individual think time for students to synthesize past research and begin listing an idea or two to present to their group. Some teachers insist that at least a part of each teammate's ideas is included in their group plan and at the least, the team should have consensus.

Name: Miguel, Maria, Tim and Julia Date: 10/2

Solution Analysis

You are ready to brainstorm possible solutions to the problem! Others may have tried to solve this same problem in the past. Research what solutions have been tried. This information may come from your stakeholder research or from new information you have gathered.

You may also have some of your own ideas of possible solutions. Each possible solution will have its own set of positive impacts and negative consequences. To decide the best possible solution to the problem you chose, follow this process with each solution you learned was already tried and those you have developed.

1. **Create a list possible solutions. Write down all the possible solutions you learned about during your research as well as your own ideas:**
    - ~~Start a campaign against pesticides use on public places.~~
    - Build fences to keep dog walkers away from the river.
    - ~~Build fences to keep people away from the river banks.~~
    - ~~Write a grant to get money to build a more modern septic system.~~
    - Work with parks department to redirect parking lot run off to a bioswale.
    - Provide dog waste collection stations and educational signs.

2. **Narrow your list down. Cross out any ideas that don't seem**
3. **realistic or do not interest you.** (Keep in mind that just because some projects will require money and/or experts this does not mean the solution is unrealistic. Groups and businesses are often willing to donate materials, their time or funds to help students with projects)

4. **Choose your top 3 solutions. You will start by analyzing only these 3 in order to decide which one you plan to complete.**

5. **Compare solutions using the Solution Comparison Table.**

6. **Choose the best solution for your project based on the Solution Comparison Table and share your choice with your teacher to get approval for your project.**

SOLUTION COMPARISON TABLE

Possible Solution Summary	**Criteria for success and positive impacts**	**Potential negative consequences**	**Stakeholder thoughts**	**Constraints that may make this difficult**	**Is the plan reason-able?**
Who was/will be involved in the project? What did/will they try? How did/will they go about their solution? When was/will this be? Where was/will this be?	What positive impacts on the environment could come from this solution?	What results of this solution could be harmful?	What might stakeholders like or dislike about this solution?	Consider time, resources, liability, etc.	Rank how likely it could be completed: 1 = low 2 = Medium 3 = High 4 = Certain
1. *Build fences to keep dog walkers away from the river.*	Dogs wouldn't be pooping near the river. Poop and excess nutrients wouldn't run into the river. Nutrients would not encourage algae blooms. Algae blooms would be reduced, so more oxygen would be available for fish. Erosion on banks will be reduced. River would be safer for people to use.	Fences will obstruct other wildlife from accessing the stream. Fence materials might introduce negative substances, such as wood preservatives, concrete, etc. Installing the fence might cause more erosion.	The dog walkers and other users will be mad they cannot easily get to the river. Park user may decline, reducing stewardship and funding for park. Dog walkers may begin to use adjacent school grounds, creating a health hazard on the school grounds.	This is going to be expensive, since the materials will cost a lot. The parks department is unlikely to support this because of the negative impact on park users. We will need adult volunteers with equipment to do a fence this large. We will need adults to run some of the equipment, such as saws. We will need to get out of classes to work on the fence.	3
2. *Remove ivy from the trees ourselves.*	Fewer nutrients would make it into river. Fewer pollutants would make it into the river. The algae blooms would get less nutrients. The algae blooms would shrink. There would be better conditions for wildlife, i.e. more oxygen, less pollutants.	The construction of a bioswale might disturb a natural area.	The construction process might irritate some users.	The parks department must support this. Funding must be allocated, although labor and design might be able to be done by volunteers. Material costs are low. Must be designed by a qualified planner and permitted.	4

Possible Solution Summary	Criteria for success and positive impacts	Potential negative consequences	Stakeholder thoughts	Constraints that may make this difficult	Is the plan reason-able?
3. *Provide dog waste collection stations and educational signs.*	People would pick up dog poop, stopping it from getting into the river. Poop and excess nutrients wouldn't run into the river. Nutrients would not encourage algae blooms. Algae blooms would be reduced, so more oxygen would be available for fish. River would be safer for people to use.	If not properly disposed of, the poop may just end up somewhere else, causing harm. The collection sta-tions might affect a natural area.	Dog walkers may be glad that they can pick up poop and be responsible (or not!) Other park users will be glad to not step in dog poop. The park staff will not have to clean up dog poop. The river users will have a healthier experience. The parks department will be implementing a good environmental practice. Dog owners would be more likely to pick up dog poop in other places.	The parks department must support this. The initial educational signs can be designed and printed at school. The parks de-partment has the resources to pur-chase the collection stations. We can install the stations ourselves using hand shovels.	4

After a solution has been selected by each team, it is time to create the plan for the project they will undertake. Students will identify and list the resources needed, the steps to implement the plan, and predict the potential outcomes. Although some of this information was part of the Solution Analysis, students may determine further research will be necessary.

Students either begin a new page in their science notebooks entitled "Project Plan" or use the scaffolded Project Plan document. The first part of the plan should address the project's purpose, including a description of the situation and how the project will solve the identified problem. The next part of the plan should address the ecosystem impacts including the location, describing the interconnectedness of living and non-living parts of the ecosystem. Students should address any pros and cons that may have surfaced when they interviewed stakeholders. Students then write a summary that describes what will be engineered to solve the problem, and how the solution will impact the ecosystem, human and non-human components. Students then create a table of resources needed and identify costs/donations. The table should include materials needed, volunteer time, ongoing maintenance, etc. Next, students write the procedures (step by step) and the timeline for their project, including dates for each step if possible and who is responsible for each step. Constraints should be listed, and students should consider how they will address them. Students determine the criteria for evaluation and how they will measure the success of their project. And finally, project contributors should be listed. For example, if your project was to solve an issue with invasive species, the criteria could include statements like - *After removal of invasive species and replanting, wildlife sightings will increase. Or more specific criteria - After removal of invasive species and re-planting of 10 native species in a .5-acre area, mammal sightings will increase from an 1-2 sightings per week to 3-4 per week as collected by area residents.*

TEACHER TIP

Helpful tips for teachers and students in planning an engineering solution:

1. Set and prioritize steps for project
2. Define "deliverables" – that is, what will be the outputs at the various steps?
3. List deadlines/make a schedule
4. Risk assessment/what could go wrong and what would you do?

Name: ______________________________ Date: _____________

Project Plan

Use details from the Solution Analysis (and any additional information gathered through research) to create a project plan.

1. Purpose: What is the problem you are trying to solve?
2. Ecosystem Impacts: Where is the problem? Be as specific as you can. Describe how this project connects to the surrounding ecosystem. How could it have positive and negative impacts?
3. Summary: In a few sentences, summarize your project and include how it will solve the problem and impact the ecosystem.
4. Table of required resources:

Resources needed:	**Source:**	**Cost or donation value:**

Total cost of the project:

5. Procedure and timeline for your project. Include dates for each step if possible and who in your team is responsible for the step. Keep in mind any further research and/or investigations you will need to complete. Include time to evaluate and possibly adjust your project plan during the process.
6. Constraints: What might cause problems or interfere with your project? How will you prepare for those limitations or challenges?
7. Evaluation: How will you measure your project's success and prove it turned out like you want and it to? Make a list of criteria that you will use to evaluate the outcomes, including measurements.
8. Project contributors: List all contributors for this project, including project teammates, experts, and stakeholders.

Name	**Title/Job**	**Organization**	**Email**	**Phone Number**

9. Project Reflection: Reflect on your project and answer the following questions.
   - What is your individual role in this project?
   - What excites you about the project?
   - What worries you?

Notes:

Mr. Gonzalez's 7th Grade Vignette: Guided FieldDesign Project

Mr. Gonzales has facilitated discussions and analysis that have led the class to a decision to address the invasive species problem by planning a project to pull the ivy themselves. They recognize that there are many components to this process, and it would be best for them to divide the first part of the project into tasks and assign teams to each.

Mr. Gonzales lists the following groups on the board:

1. Information team to make signs and let neighbors know about the project.
2. Permission and scheduling team to talk with the principal and others to decide on when to have the event.
3. Equipment/materials team to get cutting tools, gloves and any other needed items.
4. Composting team to make all arrangements for composting/disposal of ivy cuttings.

Brian enthusiastically declares, "I want to be on the equipment/materials team. My brother is taking a landscaping class at the Skills Center, and I will ask him if we can borrow tools!"

"I love making signs!" exclaims Marcie. "Can I be on the information team?"

Mr. Gonzales takes volunteers for each committee and records names on the board. Students who do not volunteer are assigned by Mr. Gonzales. Teams are now organized and given time to plan their component of the overall project.

Ms. Baker's 10th Grade Vignette: Student-directed FieldDesign Project

Ms. Baker held a whole class discussion going through all the possible solutions outlined in the Solutions Comparison table. It was clear to the class that the fencing option was not feasible. Part of the class really wanted to focus on the bioswale solution, while others liked the idea of providing dog waste collection stations.

The class decided that they would take on both projects and divide themselves into teams to work on the various components of each solution.

The bioswale project was divided into teams that would focus on:

1. Design and permitting
2. Volunteers
3. Installation event

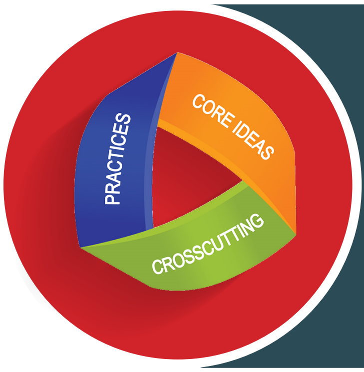
The dog waste collection project was divided into teams that would focus on:

1. Signage
2. Proposal to parks district
3. Installation event

Students were given a survey that included the descriptions of what each team would do. They indicated their first, second and third choice of teams. Ms. Baker assembled them into teams based upon their preferences, but also made sure each team had a diverse representation of skills to bring to the task. Once teams were announced, they proceeded to plan for their team's tasks.

4 STEP

IMPLEMENT AND TEST THE SOLUTION



NGSS INFORMATION:
SCIENCE AND ENGINEERING PRACTICES

- Asking Questions (Science) and Designing Solutions (Engineering)
- Developing and Using Models
- Analyzing and Interpreting Data
- Engaging in Argument from Evidence
- Obtaining, Evaluating, and Communicating Information

In addition, thinking through a way to record any changes that happen midstream should be considered. These are inevitable in most cases and designing a protocol for noting shifts in the plan will be important for both students and stakeholders. Reflecting on failures and shifts toward success is a large part of the learning in the design process.

One way to organize this is through a FieldDesign Notes organizer that students either turn in or present to the group. Facilitators can alter the FieldDesign Notes organizer to accurately depict the steps in their students' projects as needed, however it should always include reflection questions (Reasoning) to allow students to focus on the value their project.

FieldDesign Notes become a chronological record of activities, adjustments, and changes made. They will ultimately be used to summarize challenges and impacts of the choices made, evaluate the success of the project, and guide presentations describing how effective solutions were and whether optimization may be needed to better meet the criteria and constraints of the problem.

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. (from A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas, page 50)

FieldDesign Notes

As you carry out your plan, use these prompts to share the steps you have taken.

Date:

Contributors (list individuals you worked with):

Project location:

Steps:

Reflection:

- How did your actions have an impact on the project's success?
- Did your action impact ecosystem health? If so, how?
- Is the project going according to plan?

Do you need to change your plan? If so, how? (Be sure to record changes on your Project Plan if you make them)

Next Steps:

Mr. Gonzales is guiding his class through a common process to research, plan, take action, and reflect on their impact. The next step is to have all the students record their beginning FieldDesign Notes in their notebooks, as one of his goals is individual reflection on the process.

Mr. Gonzalez's 7th Grade Vignette: Guided FieldDesign Project

Mr. Gonzalez gathers the class' attention to give directions. "Class, you've done great research to help your teams build more understanding on what to consider when planning your projects. Now each team will begin to implement the steps and record notes. Please copy the projected FieldDesign Notes into your notebooks and be ready to discuss in 5 minutes."

Mr. Gonzalez knows two of his students will need support recording and he provides support for their success. Once he sees most students are finished, he continues. "Please record today's date and the members of your team in the Contributors section." As students do this, he explains, "When we take FieldDesign Notes we need to describe clearly, so when we review what happened it makes sense. Sometimes projects will not go as planned and having a precise record of decisions and data collected will help us understand why, how, and if we need to make adjustments."

The teams discuss how to fill in their specific team's tasks, and the step they will work on. Then he releases the teams to work on their projects. After the allotted time, Mr. Gonzalez gathers the class back together to reflect on their progress and explains that their reflections should be very specific and show what happened.

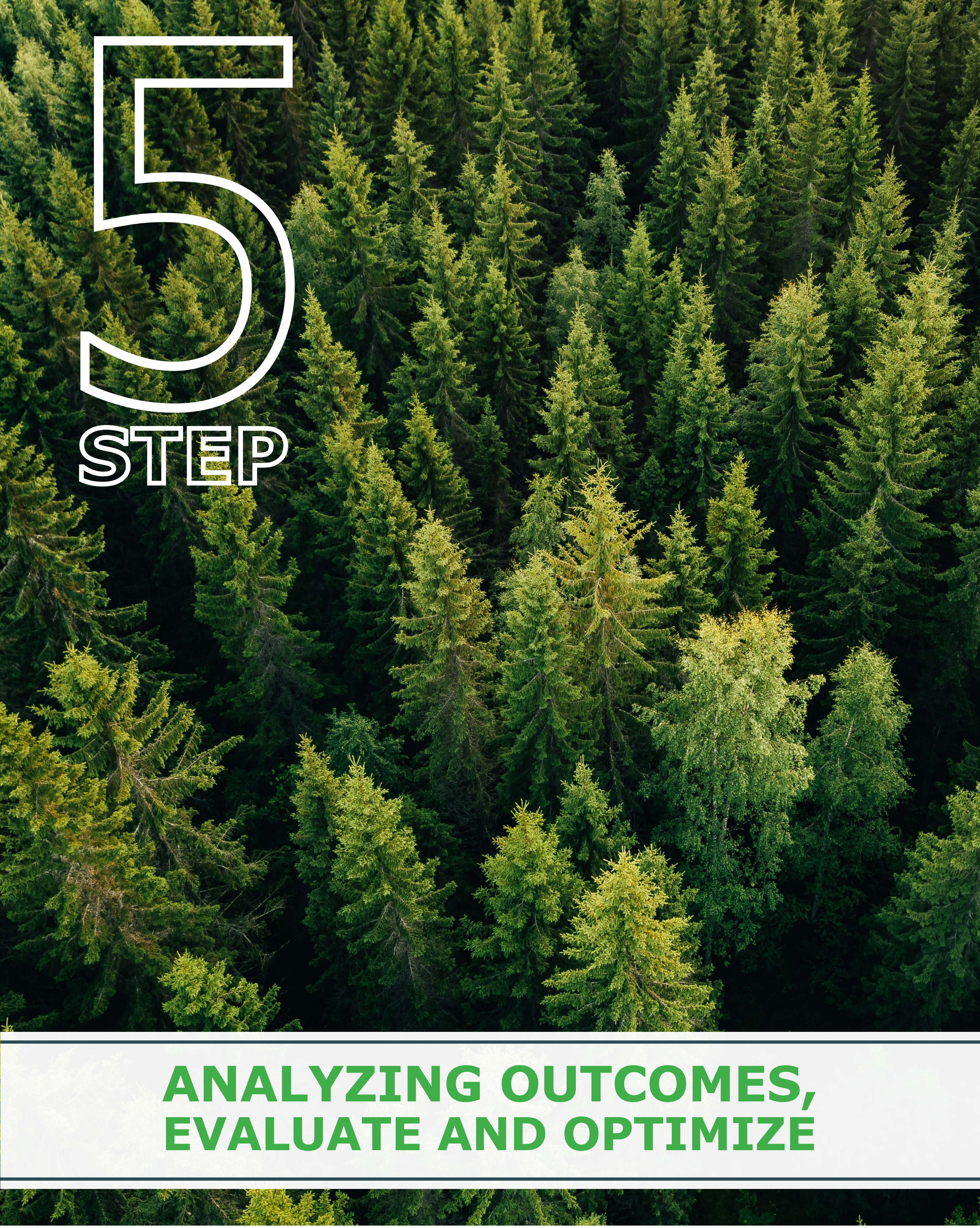
Ms. Baker is also guiding her class through a common process to research, plan, take action, and reflect on their impact. Students will be using the FieldDesign Notes in their notebooks to capture their work and individual reflections. She also has weekly online group reporting forms that the students will be completing as they go through the process, since it is critical that the teams, within each project, are clearly communicating their progress and thoughts.

Ms. Baker's 10th Grade Vignette: Student-Directed FieldDesign Project

As students enter the classroom, they notice Ms. Baker has projected the FieldDesign Notes template for the class to record in their notebooks. They record the template, then are organized into their teams to begin planning. Students complete their individual entries as they begin to outline their next steps in implementing their projects.

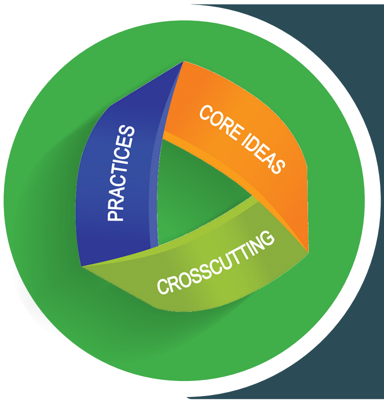
Quickly, the whole school is learning about Ms. Baker's class projects. The graphic arts teacher is answering questions about sign layout and production. The ELA teacher is helping students construct their argument to present to the Parks District to garner their support. The shop teacher is consulted about the best materials for sign construction. Students also are making calls and contacts to designers and advisors in the community.

To help the students keep all the details organized, Ms. Baker assigns an online weekly collaborative reflection sheet where each team records details on their progress and challenges. The bioswale team has one sheet and the dog waste team another. Each of these provide a record of what turns out to be a year-long process.



5 STEP

ANALYZING OUTCOMES, EVALUATE AND OPTIMIZE



NGSS INFORMATION:
SCIENCE AND ENGINEERING PRACTICES

- Asking Questions (Science) and Designing Solutions (Engineering)
- Developing and Using Models
- Using Mathematics and Computational Thinking
- Analyzing and Interpreting Data
- Engaging in Argument from Evidence
- Obtaining, Evaluating, and Communicating Information

Through a project summary presentation, students will present an analysis of their project's success and surprises. During step 5, students analyze and evaluate the outcomes of the project to prepare for their presentations and make recommendations on how to optimize the results they attained. To do this, students must consider the criteria for success, the positive and negative environmental impacts (both intended and unintended), and any data collected. This step reinforces the need for meaningful data and math in order to analyze situations and make suggestions based on evidence.

Step 5 revolves around reflective analysis and evaluation of the projects' successes and challenges and the planning for any adjustments needed to optimize the results. During steps 3-5 students may need to return to step 2 (research), based on data, questions or results, this potentially can lead to the need to pursue an entirely new solution. Sometimes this is disheartening for students who have invested a lot of time and effort. The facilitator's role is to emphasize that learning from mistakes and failures is an important part of the design process and leads to more sustainable solutions.

TEACHER TIP

A written summary, or report, is one way to check individual understanding and reflection, and there are many other ways to engage students in reflecting on their findings. Final presentations are in Step 6, so finding an active way to process reflections could help students synthesize. Some ideas include:

- Group discussions
- Organizing reflections digitally
- Creating an act/show about adjustments made and lessons learned
- Using sketching, models, or mind maps to capture ideas
- Voice recordings to talk through Project Summary, Analysis, and Evaluation Questions

FieldDesign Project Analysis

Using the statements and questions below to analyze the success of your project and make suggestions on improvements that might make the project more successful.
(refer to your FieldDesign Notes if needed):

Date:

Team Members:

Briefly describe the problem you worked to solve and how it impacts the larger ecosystem (human and non-human):

Explain why this problem is important to your community:

List the stakeholders you worked with and identify their contributions:

Summarize the project steps, including any unexpected adjustments you had to make or challenges you had to address:

Describe how your knowledge, perspectives, or opinions about the problem changed during the project? Why?

What suggestions do you have to optimize the solution?

The last question on the Project Analysis sheet is important. No matter the degree of success that was achieved in solving the problem, optimization can always occur, whether by designing revisions to the plan, decreasing project cost, adjusting how time is used, or through other improvements.

During step 5 students may find their solution was completely ineffective and they are out of time to complete the project with an optimized solution. It may be necessary to move to step 6, to present the newfound data so that others can use it as research when they work to plan a different solution to the problem. If students have time to continue to pursue the problem with an optimized solution, they would repeat steps 2-5 Stakeholder Research, Solution Analysis, Solution Comparison, Project Plan, FieldDesign Notes, and the overall evaluation once students return to step 5.

Mr. Gonzalez's 7th Grade Vignette: Guided FieldDesign Project

Students completed their team tasks. Signs were made, neighbors were contacted, plans were approved with the principal and other school staff, tools and materials are assembled, and composting/disposal plans finalized.

All of this was recorded in notebooks, on planning forms and in reflection products. The class is ready to implement their solution to the ivy problem. Finally, the day arrives and the whole class spends a couple of hours pulling ivy, dragging it to the composting area, and cleaning up their targeted site. The information team had the idea to contact the local paper and a reporter came out, interviewed students and took pictures.

Everything went according to plan, though there were some challenges. One team argued about who got to cut the ivy and who had to drag it back to the compost pile. Mr. Gonzalez suggested they take turns. Some of the trees were hard to get to, but groups of students doubled up and made a "bucket-brigade" line to haul the ivy out.

The next day Mr. Gonzales distributed the FieldDesign Project Analysis to the class. The class worked through and reflected on their project. They also came up with a plan to monitor their project over time and decide if their solution was effective over the long term. Mr. Gonzales told the class, "We will use your reflections and thoughts with next year's 7th graders to decide if we were successful, or if we will need to go back and try other solutions to eliminate the ivy."

Ms. Baker's 10th Grade Vignette: Student-directed FieldDesign Project

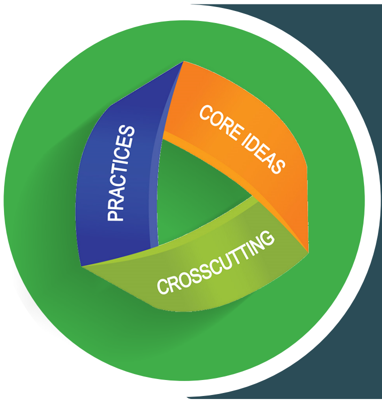
By May, Ms. Baker's class had successfully persuaded the Parks District to purchase dog waste stations. The signage team had designed, produced and installed signs in the park. The installation event was arranged for a Saturday, and families helped the students install four stations within the park.

The bioswale team had made considerable progress. They presented their proposal to the Parks Department. The Department said that there was no funding for this this year, and they were so impressed with the students' initiative and completion of the dog waste project, they would include it in the next year's budget. The students recruited a local designer to make a bioswale plan they felt certain would be good enough to get permits. A local contactor and a group of community volunteers were also committed to the bioswale project once it was started.

In order to capture everything that was accomplished and all that still was left to be done, Ms. Baker distributed the FieldDesign Project Analysis to the class. The teams worked through and reflected on their project using the forms and gathered other artifacts of their work. They created online shared folders to collect all their letters, proposals, images, press and other electronic files. This provided a permanent legacy for their work.

PRESENT FINAL SOLUTION
USING SCIENTIFIC REASONING

STEP 6



NGSS INFORMATION: SCIENCE AND ENGINEERING PRACTICES

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- Engaging in Argument from Evidence
- Obtaining, Evaluating, and Communicating Information

One of the goals of FieldDesign is to give students active and meaningful opportunities to participate in their community. Throughout the project as students share information with their teammates and the community members working with them on the project, they are practicing using new vocabulary and new information. The more opportunities they have to communicate about their projects as they are engaged in it, the more likely they will gain comfort in presenting. Even young learners should be offered opportunities to present to community decision makers so by the time they are in middle or high school they are proficient speakers and effect change in their communities; student voice becomes a valued part of the community.

Using the FieldDesign Project Presentation organizer, students present to peers and stakeholders their reasoning, plan, and impact of their project. Students should focus on the data they collected during the project as evidence of the project's success, or the need for optimization. Communicating results using scientific reasoning is a practice that "real scientists" use. Students practice their skills of utilizing and citing evidence to support scientific reasoning in their presentation. Citing evidence is an important practice in CCSS Mathematics and student competencies ELA, allowing for strong integrated learning.

Presentation types will vary depending on the audience, grade level, and need to assess student learning. Students can communicate the information as individuals or groups. Some ways for students to communicate project results include:

- Oral presentations
- Poster presentations
- Project reports
- Brochures
- Narrative writing assignments
- Video productions
- Blogs or social media posts
- Artistic performance (song, commercial, skit) or graphic art (sculpture, draw, paint)

Encourage students to communicate their findings beyond the classroom. If possible, have your class present to a wider audience. Possible audiences include the student body or School Board, relevant community organizations and stakeholders, or attendees of a regional student summit or science fair.

Each type of presentation will require some expectation guidelines from the facilitator. In general, here are some guidelines that students can use to plan their presentations, however facilitators should revise the Project Presentation Organizer to meet local opportunities, audiences, and presentation types.

FieldDesign Project Presentation Organizer

You will use the notes from your FieldDesign Project Analysis to plan the information you share during your project presentation. Use this organizer to plan how to communicate all you have learned in this process, and how successful the project was or recommendations for future work.

What was the project? (explain what you were trying to accomplish)

Why should others care about your project?

Who contributed? (including teammates and stakeholders)

When and where did your project take place?

What are your results?

Did the solution work? How did you determine whether it was successful? What method did you use to determine success based on scientific reasoning and the criteria for success?

What adjustments would optimize the results of this project if it was replicated somewhere else?

How did your thinking change because of working on this project? What have you learned?

What recommendations do you have for your school or community based on the results of your project?

After planning for the above questions, brainstorm three questions your audience may have and what your answer would be. This will prepare you for the question and answer period after your presentation.

Question	Answer
1.	
2.	
3.	

Mr. Gonzalez's 7th Grade Vignette: Guided FieldDesign Project

Mr. Gonzalez wanted his class to have an opportunity to showcase their project and hard work. They also felt that by sharing their work they might encourage various stakeholders to step in and address other invasive species on the schoolgrounds. Mr. Gonzalez asked to be included on the agenda for an upcoming school board meeting, giving the students an opportunity to share their accomplishments.

The class discussed whether having one spokesperson would be most effective, or whether having multiple speakers would be more interesting to the school board. For those who didn't want to speak, the group decided that they would create informational brochures with highlights to leave with the school board. Others created posters illustrating the projects so there would be visuals to accompany those presenting on each project. Every student had a contribution to make.

Students wanted the neighbors to have a chance to see their work, so a team of students made flyers advertising the school board presentation and distributed their invitations to all the neighbors and families in the school.

The school board was very interested in the work the students accomplished and committed to examine other options to reduce invasive species on the school grounds. The audience, filled with parents and neighbors of the school, applauded the efforts of the students.

Ms. Baker's 10th Grade Vignette: Student-Directed FieldDesign Project

Along the way the students had been noticed by various members of the community for their work, but Ms. Baker and the class wanted to pull together a formal presentation. All agreed this was critical to making sure the bioswale project would become a reality in the upcoming year, and the students had an opportunity to celebrate their accomplishments.

The class agreed they should make a video of the dog waste project. They had video footage taken on the day of installation in addition to their signage and a description of the process from beginning to end. The video would be posted on the school's website and shown at a Parks Department meeting.

The class also decided the bioswale project would have a poster presentation of their design plan, and a binder containing a narrative of the year's process, copies of all contacts and communications, lists of volunteers, and any other artifacts that would be helpful for the continuation of the project. A team of students volunteered to present this to the Parks Department and to Ms. Baker's new class the following year.

No matter whether Guided FieldDesign or Student-Directed FieldDesign processes were followed, students who engage in this learning make fluid decisions in order to tackle a real life, community impacted environmental challenge. They bump up against barriers and adjust to overcome them as adults do in their work. They work through potential frustrations and learn they have the capacity to learn from unexpected mistakes. Their learning moves through a cycle that matches "real life".

As facilitators, our role is to guide students through this process as well as monitor how we adjust our expectations of the learning steps students move through, while keeping track of progress and scheduling into timelines available. It sounds hard! But when you consider the payoff for developing students who have built confidence in their capacity for reflection and flexibility, have applied their thinking at an application level through nearly an entire unit of study and project, and who have become more connected advocates for the environment in which they live, isn't it worth a little uncertainty for the first time?

After the facilitator has guided students and groups through this learning, they should be able to look at the graphic below and recognize some of the steps their learners moved through. And, depending on the age of learners the facilitator has worked with, it may be beneficial to share with students to help highlight their flexible learning through the process as way to celebrate their dedication to finding a solution as stewards of their environment.

Appendix

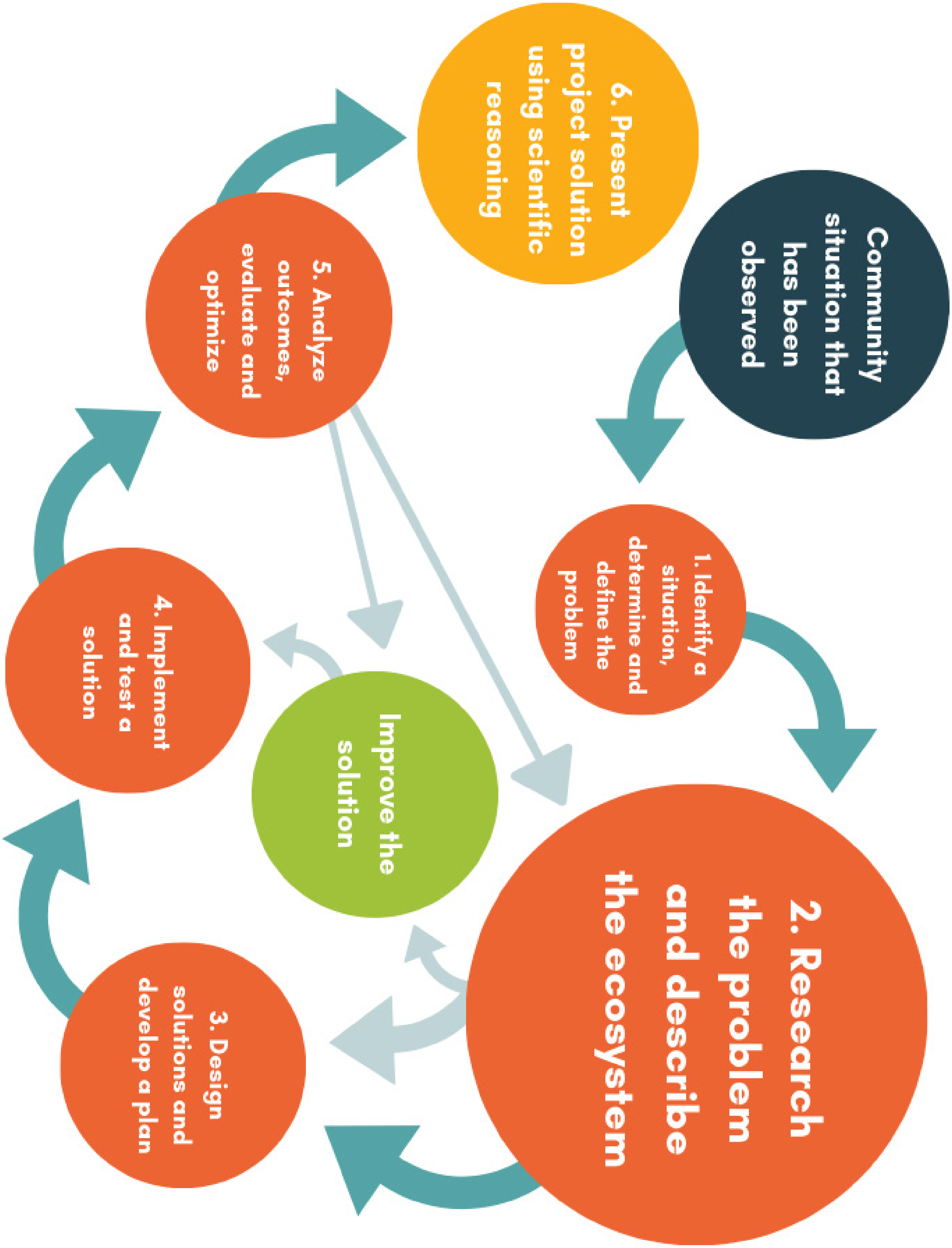
1. The FieldDesign Process

2. Guidelines for Setting up a FieldSTEM Notebook

3. FieldSTEM Notebook Strategies

4. FieldDesign Student Pages

    a. O.W.L chart
    b. Researching the Problem
    c. Stakeholder Research
    d. Solution Analysis
    e. Solution Comparison Table
    f. Project Plan
    g. FieldDesign Notes
    h. FieldDesign Project Analysis
    i. FieldDesign Project Presentation Organizer


Community situation that has been observed
1. Identify a situation, determine and define the problem
2. Research the problem and describe the ecosystem
3. Design solutions and develop a plan
4. Implement and test a solution
5. Analyze outcomes, evaluate and optimize
6. Present project solution using scientific reasoning
Improve the solution

Guidelines for Setting up a FieldSTEM Notebook

Materials needed every time you teach FieldSTEM in the classroom:

- ☐ Science Notebook (have a place to keep notebooks that stay in the classroom)
- ☐ Colored pencils/crayons (color helps the brain learn and remember)
- ☐ Glue/scotch and packing tape (to secure important data, foldables, data sheets, graphs, etc. that are essential to the learning experience)
- ☐ Highlighter (for highlighting important ideas)
- ☐ Post it notes – for collaborative conversations

Getting Set up:

- ☐ At the start of the year, discuss how FieldSTEM will be incorporated into their learning and encourage students to decorate the cover over the course of the study. Have them select one image to add during week one (covering with packing tape will help keep it down) Number the pages in the bottom right hand corner (encourage students to write really small)
- ☐ Page 1- Ensure students write their names on both the cover and on the Title page
- ☐ Page 2- Collaborative Community contract, glued in after students sign the contract
- ☐ Pages 3-6- Table of Contents (with support and modeling by the teacher, students list the date, title, and pages of each experience)
- ☐ Select 4-6 pages at the end for the Glossary.
- ☐ For stronger notebooks: Open notebook to the center stapled page. Slide in a rubber band (size 31/2 x 1/16 works well), binding the pages to the front cover. Close notebook. Reinforce the spine of notebook with packaging or duct tape.

Key Final Thoughts:

- ☐ Make the FieldSTEM Notebook design work for you and how you structure your classroom
- ☐ Model FieldSTEM Notebook use for your students.
- ☐ To the extent possible have students create their own forms, tables, graphs etc. and differentiate with pre-made sheets as necessary.

FieldSTEM Notebook Strategies

Using modeled scaffolds (graphic organizers, writing frames, etc.) where there is a gradual release of responsibility toward creating these independently, FieldSTEM notebooks promote the development of English language arts and math skills by utilizing them in service of engaging, locally important problems, issues, questions and opportunities.

While FieldDesign provides templates for organizing student work, educators must resist the temptation to provide pre-made scaffolds, worksheets, data chart, etc. for students and instead encourage students to embrace their need to learn and grow in their skills. Students will learn to develop effective tables for data collection only if they are allowed to struggle with the number of rows and columns and how to label them. Ultimately, opportunities like these provide students with the skills to think critically, work and communicate in collaborative ways and make informed decisions on behalf of their community.

There are many strategies to engage student in utilizing their FieldSTEM notebook. A few are listed here. PEI readily admits these strategies have been used in classrooms for decades and called many things, we offer them here as examples of ways to utilize FieldSTEM notebooks.

Notebook Strategy: Developing Student Thinking

At PEI we promote students' sense of wonder. The following FieldSTEM notebook strategy will encourage this sense of wonder while simultaneously developing student thinking.

Left Side/Right Side
In a FieldSTEM notebook, you would model:

LEFT SIDE
Output

Student generated entries on this side demonstrate understanding of the information on the right side, focuses attention, guides student learning of content and concepts, and are a good resource for student created investigations and focus questions.

Every left side page gets used.

Entries can include:

-brainstorming	-self reflection
-photos	-illustrations
-models	-diagrams
-poems	-concept maps
-songs	-design process ideas
-questions	-wonderings
-mapping	-flow charts

RIGHT SIDE
Input

Information from other sources including teachers, texts, observations from activities.

Entries on this side are connected to learning goals, capture content, ideas and evidence for future reference, provide assessment and feedback opportunities and drive instruction.

Entries can include:
-focus question
-mapping
-field investigation notes/data
-vocabulary
-speaker, text or video notes
-lab activities
-entry types; data tables,
-date, time, location, weather
-diagrams, comparisons

Notebook Strategy: Collaborative Communication

Evidence of a student's conceptual understanding can be communicated by assessing the student's thinking, skills and understanding of content in their FieldSTEM notebook. Look for evidence of these elements and others in what they've captured in their entries. Utilizing the Next Generation Science Standards evidence statement for any given
performance expectation may be useful. Engage in collaborative conversation around the entries: teachers and other students who have been coached on constructive feedback can provide input on a "post it note" or orally. Strengths should point to specific information and examples and how they meet the criteria/evidence statements. Weaknesses should be addressed in the form of a question that a scientist or an engineer would as, "Do you think another engineer would need more information to understand?". An effective collaborator will eliminate vague feedback like "good job" and use questioning strategies. A sample of FieldSTEM notebook entry questions that help a collaborator understand and move another person's thinking forward are:

- What did you observe that makes you think that?
- What evidence do you have to support your thinking?
- Have you recorded your evidence accurately?
- Do your results support your prediction? If not, how has your thinking changed?
- Are there people in the community that would agree with this thinking?
- What do you think happened during your project that led to inconsistent or inconclusive data?
- Have you reread your entry to see if any changes are needed to make it more clear or accurate?
- What are your next steps?

Notebook Strategy:
Sentence Frames for Differentiated Instruction

To help students become independent writers it is important to model how to organize the thinking and evidence they capture in their FieldSTEM notebooks. With consistent modeling and support and then a gradual release of responsibility with writing frames, you are providing a tool for emerging writers that allows students to use ELA skills successfully to access STEM in the world around them and share their thinking with others. These frames can be used for sharing evidence orally as well. Simply post the phrases in a pocket chart or on a bulletin board then model and practice their use.

Elementary FieldSTEM Notebook Writing Frames

Observations:	I observed_____.
Compare:	A ___ has ____ and ___, a ____has ___and____ and both have ___.
Contrasts:	_____, but _____.
	At first, _____, but now_____.
Sequence of Time:	First,_____. Next,_____. Then,_____. Finally,_____.
Predicting:	I predict that _____will _____because_____.
Cause and Effect:	_____because_____.
	If_____, then_____. So,_____.
Reasoning:	I think_____, because_____ .
	_____because _____.
	At first, I thought___, because___. Now I think____, because____.
Conclusions:	For the following reasons_______, and______, I think _____.
Claims and Evidence:	I think ____ because ___. If you do ____ then _____ because ___.

Notebook Strategy:
Activating prior knowledge and preconceptions

Goal: To help students identify what they have already experienced or observed about the topic and to make connections.

Capture student thinking:

- On a O.W.L. chart or another graphic organizer
- Individually, in groups, or as a whole class
- Sparked by a different content area connection (i.e. poetry or art on the topic)

Possible prompts:

- What does (project topic or term) make you think about?
- Have you _________ before?
- What do you think about when you look at …?

O.W.L.: Human Impacts on Our School Grounds		
Observations	**Wonderings**	**Learnings**

Researching the Problem

1. In one sentence, describe *the problem* you're planning to solve:

2. Why is this problem important? What will happen if no changes occur?

3. What I already know that may help:

4. What I need to know before starting:

5. Where I might find the information (books, websites, experts, etc.):

Researching the Problem (Continued)

My notes (cite your sources):

1. **The problem (complete sentence):**

2. **Criteria (goals):**

3. **Constraints (limitations):**

4. **What I know now that may help:**

Stakeholder Research

Stakeholder name (individual, organization, business, agency):

Stakeholder website:

Contact name:

Contact phone number/email:

How is this stakeholder connected to the problem?

Is the stakeholder aware of the problem? If so, what are their opinions about it?

If the stakeholder owns the land where the project would take place:

- **How do they currently use the land?**
- **Does that use of the land impact the problem? If so, how?**
- **Are they trying to be environmentally friendly? Explain.**
- **Are there laws that affect the way the stakeholder can use the land?**
- **Are there any culturally or familial connections that ties the stakeholder to the land?**

How could the problem affect the stakeholder now and in the future?

How could the stakeholder contribute to the problem?

How could they be a part of the solution?

Would the stakeholder like to play a role in this project? If yes, what role?

Would the stakeholder be interested, financially, in finding a solution?

Solution Analysis

You are ready to brainstorm possible solutions to the problem! Others may have tried to solve the same problem in the past. Research what solutions have been tried. This information may come from your stakeholder research or from new information you have gathered.

You also may have some of your own ideas of possible solutions. Each possible solution will have its own set of positive impacts and negative consequences. To decide the best possible solution to the problem you chose, follow this process with each solution you learned was already tried and those you have developed.

1. **Create a list of possible solutions. Write down all possible solutions you learned about during your research as well as your own ideas:**

2. **Narrow your list down. Cross out any ideas that don't seem realistic or do not interest you. (**Keep in mind that just because some projects will require access to expert opinions or money, it doesn't mean the solution is unrealistic. Groups and businesses are often willing to donate materials, time, and resources to help students with projects)

3. **Choose your top 3 solutions. You will start by analyzing only these 3 in order to decide which one you plan to complete.**

4. **Compare solutions using the Solution Comparison Table.**

5. **Choose the best solution for your project based on the Solution Comparison Table and share your choice with your teacher to get approval for your project.**

Possible Solution Summary	**Criteria for success and positive impacts**	**Potential negative consequences**	**Stakeholder thoughts**	**Constraints that may make this difficult**	**Is the plan reasonable?**
Who was/will be involved in the project? What did/will they try? How did/will they go about their solution? When was/will this be? Where was/will this be?	What positive impacts on the environment could come from this solution?	What results of this solution could be harmful?	What might stakeholders like or dislike about this solution?	Consider time, resources, liability, etc.	Rank how likely it could be completed: 1 = low 2 = Medium 3 = High 4 = Certain

Name: ______________________________ Date: _____________

Project Plan

Use details from the Solution Analysis (and any additional information gathered through research) to create a project plan.

1. Purpose: What is the problem you are trying to solve?

2. Ecosystem Impacts: Where is the problem? Be as specific as you can. Describe how this project connects to the surrounding ecosystem. How could it have positive and negative impacts?

3. Summary: In a few sentences, summarize your project and include how it will solve the problem and impact the ecosystem.

4. Table of required resources:

Resources needed:	**Source:**	**Cost or donation value:**
Total cost of project:		

Project Plan (Continued)

5. Procedure and timeline for your project. Include dates for each step if possible and who in your team is responsible for the step. Keep in mind any further research and/or investigations you will need to complete. Include time to evaluate and possibly adjust your project plan during the process.

6. Constraints: What might cause problems or interfere with your project? How will you prepare for those limitations or challenges?

7. Evaluation: How will you measure your project's success and prove it turned out like you want and it to? Make a list of criteria that you will use to evaluate the outcomes, including measurements.

8. Project contributors: List all contributors for this project, including project teammates, experts, and stakeholders.

Name	Title/Job	Organization	Email	Phone Number

Project Plan

9. Project Reflection: Reflect on your project and answer the following questions.

- What is your individual role in this project?

- What excites you about the project?

- What worries you?

Notes:

FieldDesign Notes

As you carry out your plan, use these prompts to share the steps you have taken.

Date:

Contributors (list individuals you worked with):

Project location:

Steps:

Reflection:

- **How did your actions have an impact on the project's success?**

- **Did your action impact ecosystem health? If so, how?**

- **Is the project going according to plan?**

Do you need to change your plan? If so, how? (Be sure to record changes on your Project Plan if you make them)

Next Steps:

FieldDesign Project Analysis

Using the statements and questions below to analyze the success of your project and make suggestions on improvements that might make the project more successful. (refer to your FieldDesign Notes if needed):

Date:

Team Members:

Briefly describe the problem you worked to solve and how it impacts the larger ecosystem (human and non-human):

Explain why this problem is important to your community:

List the stakeholders you worked with and identify their contributions:

Summarize the project steps, including any unexpected adjustments you had to make or challenges you had to address:

Describe how your knowledge, perspectives, or opinions about the problem changed during the project? Why?

What suggestions do you have to optimize the solution?

FieldDesign Project Presentation Organizer (continued)

After planning for the above questions, brainstorm three questions your audience may have and what your answer would be. This will prepare you for the question and answer period after your presentation.

Question	Answer

PEI

PACIFIC
EDUCATION
INSTITUTE