



Taking Action!

A learning approach that empowers youth
to generate solutions for their communities



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Introduction

Increasingly, our world presents us with complicated, interdisciplinary problems that have foundations in science, technology, engineering, and mathematics (STEM). Whether we need a modification of a vaccine to challenge a virus variant, a sensor to monitor methane emissions on offensive garbage cans in urban areas, or the ability to design a water filtration system to increase the availability of potable water, we need to provide opportunities for our youth, ages 10-18, to deepen their learning through the creation of solutions to local challenges. Recent surveys in the United States reveal that the average time devoted to teaching science in US elementary schools is 20 minutes per day, a few days a week (NRC, 2021). Therefore, as teachers, parents, scientists, engineers, community members, and policymakers, we have a societal duty to empower adolescent students to ask questions, engage in scientific investigation, and work cooperatively with others to generate sustainable solutions to present and future interdisciplinary problems. The recent President of the National Academy of Sciences in the United States stated, “Today unless we can spread both scientific thinking and these critical scientific values much more broadly

throughout society, I fear for humanity’s survival.” (Alberts, 2022).

In the United States, the Next Generation Science Standards have changed our expectations of how to teach science. The most notable change has been the shift from students learning science as disconnected ideas toward learning science content (disciplinary core ideas and crosscutting concepts) through science and engineering practices (NRC, 2012). Instructional programs that extend the learning of STEM topics through solutions challenge the science education status quo. Many secondary curricular programs promote learning science content through science practices such as arguing from evidence and planning and carrying out investigations. Yet, the focus on learning science through the engineering design of solutions is less common. Even fewer instructional programs highlight science learning through both scientific investigation and engineering design in tandem, even though crucial policy documents (e.g., National Research Council, 2012) identify learning science through both the practices of science and engineering as a mutually beneficial, creative, and iterative process (NRC, 2012).

Eco-solutioning Instructional Model

Phase	Description
Engage	Students ask questions associated with an introductory activity that engages their curiosity and provides a purpose for why they are studying local environmental issues.
Explore	Students collect data on animal/plant species within their local neighborhood to use as evidence to address a problem in their neighborhood.
Explain	Students use evidence from the Explore phase students construct an argument to address a scientific question.
Engineer	Students extend their understanding through the design of traps and a plan that meet specific design criteria and constraints. Students test their trap designs through data collection to determine if their solution is optimal for addressing the problem.
Educate	Students synthesize guidelines from their plan to inform and educate key stakeholders about the ways the plan might be implemented in their own and other local regions.

Table 1: Eco-solutioning Instructional Model

This e-book describes a learning approach, Eco-solutioning, that guides youth to deepen their learning of biology content through the practices of both science and engineering. In addition, this e-book provides examples of activities and student work which illustrate our approach to learning interdisciplinary science content through investigation and engineering design.

Learning Biology through both the Practices of Science and Engineering

Even as the creators of the Next Generation Science Standards distinguish between the endeavor of science and the endeavor of engineering (NGSS Leads States, 2013), they explicitly discussed how the two endeavors are mutually beneficial. The authors distinguish between the practices of science and engineering in two places:

1. **Practice 1** is Asking Questions (for science), Defining Problems (for engineering) and
2. **Practice 6** is Constructing Explanations (for science) and Designing Solutions (for engineering) (NGSS Leads States, 2013).

Indeed, learning approaches have often unintentionally emphasized learning science through either the practices of science or engineering but not both. For example, the 5-E learning model (Bybee, 2006) emphasizes learning science through inquiry investigations. Other programs emphasize learning science through only the practices of engineering (Guzey et al., 2017; Crotty, Guzey & Roehrig, 2017). Policy documents also emphasize that teaching through only one kind of practice often masks the interconnected nature of the two pursuits. Drawing inspiration from this idea, our learning approach intentionally and explicitly emphasizes learning biology content through science and engineering practices.

Eco-Solutioning

What would a learning approach look like that fosters science learning through scientific investigation and the engineered design of solutions? Table 1 provides an overview of the five phases of our learning approach, called Eco-Solutioning. Eco-solutioning builds on the 5-E learning cycle (Bybee, 2006) and uses a similar sequence for the first three phases,

Science Standards, Eco-Solutioning Phase, and Lesson Goals	
NGSS (MS-LS-2-4) and State Standard (6.6.4): Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.	
Lesson 1:	What species live in my neighborhood? (Engage and Explore phases)
<ul style="list-style-type: none"> • Collect local data on animals in your schoolyard. • Collect local data on the kinds (richness) and amounts (abundance) of local species on a field trip. 	
Lesson 2:	How do invasive species populations disrupt native populations? (Explain phase)
<ul style="list-style-type: none"> • Interpret local data to provide evidence of the kinds and abundance of animal species in your community. • Gather, read, and communicate information from multiple appropriate sources on one local species including information about resource needs, behaviors, habitat, and seasonal patterns. • Use models to make a prediction about the dynamics of predator/prey relationships. • Construct an argument to address the scientific question, Does an invasive species disrupt populations of native species? 	
Lesson 3:	How Does Our Eco-Solution Plan Help Reduce the Number of Invasive Species? (Engineer and Educate phases)
<ul style="list-style-type: none"> • Develop an eco-solution plan based on specific design criteria to decrease populations of invasive species in the local community. • Construct an argument to address the scientific question, <i>How will our eco-solution plan decrease populations of a local invasive species?</i> • Communicate information through presentations and writing to inform others about your eco-solution plan and evaluate competing design solutions for decreasing invasive species. 	

Table 2: Science Standards, Eco-Solutioning Phase, and Lesson Goals

Engage, Explore, and Explain. In these phases, students learn about local animals, invasive insects, biodiversity, and food web disruption through asking questions, collecting data on the kinds and amounts of local animals they observe, analyzing their data, and using their data to construct arguments about animal abundance and species richness in their local community.

The fourth and fifth phases, Engineer and Educate, guide the learning of life science content through engineering practices, including the design and testing of an eco-solution plan to trap or mitigate a local invasive insect. In Educate, students select vital components of their trap design or their solution to share with local community members and others. The instructional materials consist of six weeks of field-based activities, field-based resources for students’

identification and organization of their observational data on local animals, assessments and rubrics, and teacher professional development resources. Table 2 provides an overview of the science standards, lesson goals, and Eco-solutioning phases for the entire unit. Overall, the sequence of learning goals illustrates a plan for how individual learning goals build on one another to deepen the understanding of the science content through engagement with the practices of both science and engineering. For a complete look at the instructional materials, please visit our website.

Examples of Activities and Student Work

In this section, we provide examples of activities and student work generated from two rounds of implementation with youth ages 11-14. Research studies were conducted with 94 students and three

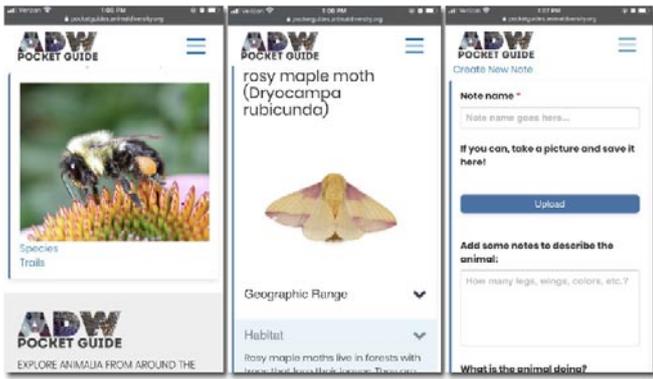


Figure 1: The ADW Pocket Guide

teachers from three culturally, racially, and linguistically diverse schools. Results demonstrated that students achieved significant learning gains after involvement in the eco-solutioning programme (Songer and Ibarrola Recalde, 2021).

The program begins with **Lesson 1: What Species Live in My Neighborhood**. In these activities, student learning is organized around a series of field-based activities that guide students in making observations of local animals using a field-based tool, the Animal Diversity Web (ADW) Pocket Guide. The ADW Pocket Guide (Figure 1) was created specifically for youth field-based data collection and analysis. The tool provides access to images and information on the

animal species students are most likely to observe in their geographic region.

The curricular activities provide several instances for students to gather data about animals near their school or in a local park. The first observation is relatively unguided, providing students with an opportunity to develop a working knowledge of what constitutes a good observation. In the second observation, students are tasked with creating at least five notes with evidence of animals observed and pictures, if available, of the animals they observe using the ADW Pocket Guide tool. After all field-based observations, student data are organized into a class spreadsheet (Figure 2) and for the creation of bar graphs used for evidence in argument construction (Figure 3).

Next, the teacher leads a sensemaking class discussion about the definition of biodiversity and the scientific terms abundance and species richness, using students' data to explain these terms. The teacher fosters the conversation with questions such as "what data did you use as evidence to determine species abundance?" or "Did anyone use different data to come to their conclusion?" After students analyze their data, they draw on it to construct scientific arguments. Students then return to their data to re-evaluate what their data indicate. Students also use an

Name	First	Last	Images	What Kind Of Animal Do You Think This Is?	How Many Animals Did You Observe?	Where Specifically Did You Observe The...	What Is The Weather Like?	In What Kind Of Habitat Did You...	What
[Redacted]				roly-poly bug aka pill bug	1	on the ground	clear but foggy	rolling in the dirt in warm areas	rol
[Redacted]				idk prolly a worm, an ant, and a ladybug.	0	the internet.	warm	dirt.	
[Redacted]				idk prolly a worm, an ant, and a ladybug.	0	the internet.	warm	dirt.	
[Redacted]				roly-poly bug aka pill bug	1	on the ground	clear but foggy	rolling in the dirt in warm areas	rol
[Redacted]				An earwig.	1	On a leaf.	It looks nice and cool.	It looks like it is in the forest.	It is cra
[Redacted]				A Beetle I don't know what kind of beetle tho	1	by the portables (no I didn't find it by the portables on google)	overcast looks like its going to rain	the schools backyard	prob somett
[Redacted]				Monarch Butterfly, I don't know the name tho	3	On a flower, On a leaf and on another leaf	Sunny, warm, good weather	Grassland	Butterf

Figure 2: Data organized into a class spreadsheet

online learning platform with resources such as age-appropriate scientific term definitions, readings, and examples of biodiversity and how it is calculated.

In Lesson 2: Ecosystem Interactions, students again collect data, analyze data for evidence, and construct arguments. This lesson begins with students collecting data from a simulation around invasive insects. Students utilize the simulation to make predictions of ecological stability and possible changes in population numbers with the introduction of invasive species. The analysis compares the differences between population numbers of bugs, grass, and birds before and after the introduction of the invasive insect. The study provides evidence for students to create an argument to address the scientific question: Are invasive insects harmful to other organisms?

In Lesson 3: Reducing the Number of Invasive Species, students begin their engineering task with a letter from the Department of Agriculture that tasks them with designing traps to reduce the number of one of a set of local invasive insects in their area. The letter asks student teams to consider the following constraints:

1. Cost of implementation (\$200 to create their traps).

2. The amount of time (2 hours to set up the traps).
3. Maintenance of the traps (weekly to change trap parts or dispose of captured insects).

As a first step in preparing for their design, students conduct background research on their invasive insect, including their life cycle, seasonal constraints, diet, how it impacts the local environment, and predators (usually none). Then students go outside to study their schoolyard and possible locations for their traps. For example, the students might select locations for their traps near bodies of water since many insects congregate around there. On the other hand, they might determine that water sources are inappropriate as they might collect native insects instead of invasive ones. Students then work in teams and with the supplies provided to create a prototype of their trap design. The prototype represents the culmination of the work in deepening their understanding of local ecology through science and engineering practices.

Figure 4 presents plans and trap designs for capturing two different invasive insects: the spotted lanternfly common in the eastern United States and the brown marmorated stink bug, which is common in the high mountain desert of the United States.

Neighborhood Animal Reports

1. Open your notes you took on your AEW Pocket Guide (the notes you just uploaded into gogo).
2. Refer to your notes, and talk to members of your group, to fill in the following chart "Our Group's Data" with your group.
 - a. Note: there should only be one animal per row - even if more than one of you counted that animal. Just total your counts. (For example, if you saw 3 house flies, and someone else saw 2, record "house fly" on one row and put the total count as "5".)

Neighborhood Animal Report: Our Group's Data

Animal name	How many did our group see? Count
E.g. Common House Fly	5

3. Once you have completed the table with all your group's data, someone in your group should raise their hand. Your teacher will then send your group up to the board to fill in the organism names and counts from your group's data table above. If another class member (from a different group) has already written the name of one of the organisms that you also have on your data table, just add your count to theirs.
4. Once your teacher instructs you to do so, fill in the whole-class data table below by using the data set from the board.

Neighborhood Animal Report: Our Class's Data

Animal Name	How many did our class see? Count
E.g. Common House Fly	1

5. After filling out the whole class data table, use it to create a bar graph in the space provided below. (If this bar graph doesn't provide you with enough space, you may create your own on the backside of this paper.)

Bar Graph of Class Animal Observations

Modification: This worksheet is designed for students who need scaffolding to work with raw data. If students have worked with analyzing data, then the directions for creating the graph can be taken out and students can work with a blank graph sheet to show their results.

Figure 3: Spreadsheet for the creation of bar graphs used for evidence in argument construction

Conclusions

The world's challenges are not simple, and the solutions that address these challenges require engineering design, creativity, testing, and practice. Such solutions also require thinking beyond traditional approaches and narrow boundaries of current science learning. Instructional strategies such as Eco-Solutioning guide students to not just learn ecology and biodiversity concepts but to take action and use their disciplinary knowledge to design interdisciplinary solutions. Such thinking is crucial for all our futures.

Authors

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Notes:

Life Right Here and Everywhere is funded by the National Science Foundation (2125844). If you are interested in learning more about the project please see our website, <https://lrhe.utah.edu/>

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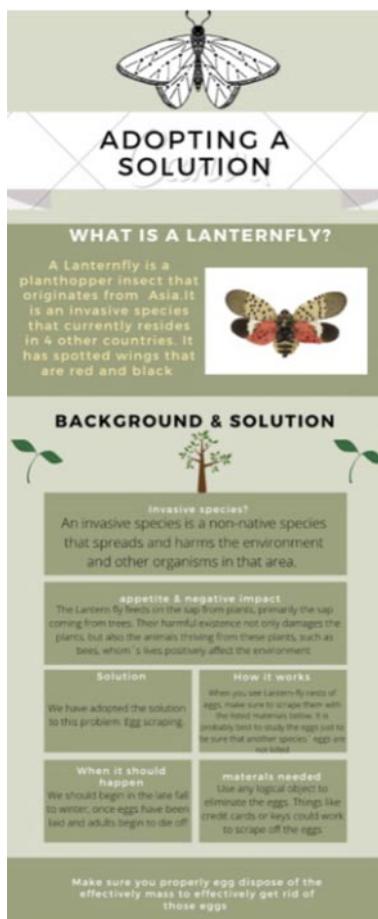


Figure 4: (left) Solution for capturing the Spotted Lanternfly. (right) Background and trap design

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FOR CAUSING SERIOUS DAMAGE TO OUR TREES



SPOTTED LANTERNFLY

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