CASE STUDY 5

Girls and the Next Generation Science Standards

Abstract

Despite gains in science achievement scores, girls lag behind boys in every grade tested in the National Assessment of Educational Progress (NAEP). By the time girls reach high school, a disproportionate number steer away from advanced courses in science – physics, engineering and computer technology – limiting their options for STEM (science, technology, engineering, and mathematics) college degrees or careers. Research points to three main areas where schools can positively impact girls' achievement, confidence and affinity with science: (1) instructional strategies, (2) curricular decisions, and (3) classroom and school structure. The Next Generation Science Standards (NGSS) pave the way for increased exposure to all disciplines of science for all students. This is a breakthrough, in particular, for girls, as research attributes gender disparities in science achievement, college graduation, and career success to an early "experience gap" between girls and boys. The vignette below highlights an early exposure to engineering through a forest restoration project that girls found engaging. It underscores how the purposeful inclusion of effective strategies for girls can have a positive impact on their confidence as beginning scientists and engineers.

Vignette: Defining Problems with Multiple Solutions within an Ecosystem

While the vignette presents real classroom experiences of NGSS implementation with diverse student groups, some considerations should be kept in mind. First, for the purpose of illustration only, the vignette is focused on a limited number of performance expectations. It should not be viewed as showing all instruction necessary to prepare students to fully understand these performance expectations. Neither does it indicate that the performance expectations should be taught one at a time. Second, science instruction should take into account that student understanding builds over time and that some topics or ideas require extended revisiting through the course of a year. Performance expectations will be realized by utilizing coherent connections among disciplinary core ideas, scientific and engineering practices, and crosscutting concepts within the NGSS. Finally, the vignette is intended to illustrate specific contexts. It is not meant to imply that students fit solely into one demographic subgroup, but rather it is intended to illustrate practical strategies to engage all students in the NGSS.

Introduction

The following vignette highlights an example from each of the three main areas—teaching strategies, curricula, and organizational structure—that raise achievement and confidence in science for girls. The unit described in this vignette (based on Earth Partnership for Schools Program, 2010) illustrates how outcomes for engineering practices can be achieved through a project that young girls find engaging. Engineering, practiced by far fewer females, has a particular appeal for the girls in this vignette because the practices are developed around the core content in life sciences, a discipline with which more girls tend to identify.

Although the unit – improving habitats for forest wildlife – focuses on the natural world rather than the designed world, the practice falls squarely within the realm of engineering (solving a problem) more than science (answering a question). The vignette begins after a unit on ecosystems to meet the performance expectations for “Matter and Energy in Organisms and Ecosystems.” Recognizing that the students needed to be more engaged in thinking about the importance of ecosystems, Ms. G., the teacher, extended the ecosystem unit using additional activities to meet specific performance expectations related to “Engineering Design.”

Through the course of the unit, many of the girls in the class are transformed from passive observers to active participants solving a real world problem. As a result of careful planning on the part of their teacher, the girls proudly call themselves “engineers” and choose to take on leadership roles. Ms. G. uses the project-based inquiry model as well as literature and design to spark her girls’ interest in engineering. Ms. G. additionally encourages the girls to join the after-school science club, allows them to form all-girl teams, and reinforces the message that science is for everyone. In the vignette, Cassidy, Aurelia, Annika and Kailey use science practices and content to identify, assess, and solve a problem that has important real world consequences. Through this experience, they gain an understanding of the application of science toward engineering solutions, and thereby establish a foothold in the world of engineering. Throughout the vignette, classroom strategies that are effective for all students, particularly for girls according to the research literature, are highlighted in parentheses.

Connections to Girls in Science and Engineering

Engineering: The solution. Kailey, a 3rd grader, stood ready to speak in front of the entire 3rd grade at her school. Three classrooms of students were sitting cross-legged on the floor of the school’s cafeteria. She and her classmates were about to present the forest management problem and its solution. Kailey was the student in her class most eager to present. Annika, Aurelia, Billy and Josh were next to her, more shy but equally excited about the project.

After a few words from the teacher, Kailey stepped forward. She began by stating the question: “Do our woods give the animals enough food?” Next to her was a large colorful phenology wheel (Forbes, 2008) that showed the evidence that the class had assembled.

Kailey read from the cue cards she and her class had prepared: “In the fall, our class did a habitat activity in the woods.” An appreciative murmur sounded in the cafeteria; many students had enjoyed activities in the woods. “We counted trees, shrubs, flowers and old logs. We counted dens and nests. We were looking for signs of food and shelter, things that all forest animals need in their home, or habitat. We wanted to see where food comes from in our woods.”

Kailey passed the cue cards to Josh. He continued, listing and describing the food sources in the school woods, including seeds, fungi, insects, leaves and smaller creatures eaten as prey. Next, Annika spoke: “After we learned all the kinds of food in our woods, we wanted to know in what months that kind of food was available. So we made this calendar-wheel, which shows the months of the year. You can see on this wheel that some foods, like fungi and meat from creatures, are available in the woods all year.”

Annika took a breath and remembered to slow down. “You can also see on our wheel that there are white spaces. The white spaces show when food is not available; so this ring shows that nectar from flowers is available only in April, May, and June, but not in July, August, September, or October. Since every white space shows a time when food is not available, some animals might not have enough food in those months. We decided to try to make our woods a better home for animals."

Aurelia held up a large picture of a white flower, Annika handed Billy the cue cards, and he stepped forward to finish the presentation. "We learned about a native woodland flower, the arrow-leaf aster that blooms in the late summer and all fall until the frost comes. This will make the flower nectar available for bees and other pollinators for a much longer time. So we thought it would be good to plant it in our woods. And the good news is we can! Ms. G. ordered enough plants from a native plant nursery so each class can plant some." Billy glanced up at the crowd and added, "Next year, in the fall, we will check to see if our plan worked by doing a flower observation and looking to see if bees are using the flowers."

The 3rd grade applauded enthusiastically at the close of the presentation, and Annika, Aurelia, Josh, Billy, and Kailey stood proudly next to their classmates. The effort to enhance the school woods was on its way to becoming a success. Their teacher, Ms. G., was very proud of her students and reflected on how far they had progressed through the project activities.

Planning an investigation. Ms. G. was a seasoned teacher with a passion for getting students outside. She took her students out to the nearby school woods weekly or biweekly and tried to figure out creative ways to meet the science standards through the lens of the forest. She found that the forest and the outdoors engaged her students because they could see the science. This year, she was determined to achieve the engineering objectives in the school woods as well. Through this effort, she knew the forest study would engage the girls as much as the boys, and she would enlist her students as lead partners in tackling an engineering design problem.

Ms. G. had a group of 20 3rd graders, 12 girls and 8 boys. About half of the students lived in the town of 1,400 and in outlying subdivisions, and the rest lived on farms and arrived on buses every morning. Over the years, she found that a few students came to school having had time to explore natural areas on their own. When the class went outside, these students tended to notice more than the other students about their natural surroundings. However, as the year progressed, more of her students could describe the forest, its seasonal changes, and the interdependence of living things in the wild. Through engineering design, she planned to engage her students as active participants in the forest investigation.

She began the engineering project by setting the stage for her students to identify an engineering problem. She proposed a question for investigation: "Are our woods a good home for wildlife?" (*Ms. G. chose a curriculum topic that had relevancy and real-world application, an angle that would purposefully interest and engage the girls in the class.)*

Her students, sitting in desks facing the whiteboard, were silent. Ms. G. waited. After a minute, Aurelia raised her hand. Her family had a CSA (community supported agriculture) farm, and she was very knowledgeable about plants. Billy raised his hand next. Billy, another confident student, spent hours out in the forest hunting with his father. Ms. G. waited another minute as a few more hands went up. She acknowledged the students who wanted to share and nodded to Aurelia.

"Ms. G., I think our woods are a good home for the animals! The deer… raccoons, chipmunks, and lots of birds…like cardinals and woodpeckers…there is pretty much nature. Last Tuesday when…we were pulling out the buckthorn, we saw that fat toad, and remember?" She looked around and dreamily said, "He was so *happy*." Some of the students laughed; that toad *had* seemed extremely pleased with himself. Ms. G. laughed too, and then called on Billy. "I think so, too. The woods are a great home," he continued. "Animals aren't like people. They are okay with a hard life, even, because that's what they're used to. They just run and survive in the woods. If they are *there,* then it's a good home, if they have enough food." Abby spoke up with a question, "How do we know for sure? I'm wondering: if it's such a great home, why don't we see a lot more animals?" (Practice: Asking Questions and Defining Problems.) Billy said, "We know that they are hiding, and that's why we don't see them! Animals are really good at hiding and blending in."

After a few more responses, and a few animal anecdotes, Ms. G. said, "I want to go back to Abby's question, "How *do* we know for sure that our woods are a good home for the animals? How could we find out? Today, when we walk in the woods, I want you to think like wildlife biologists. Does anyone know what a wildlife biologist does?" Ms. G. waited, but this time no one ventured a guess. She asked again, "Does anyone know what a wildlife biologist might *look for* in our woods?" Again, the class was silent, and Ms. G. tried another approach, "Remember our visitor, Ms. DeNotter? She is studying to be a herpetologist, a reptile expert, which is a kind of wildlife biologist." (*Ms. G. previously had brought in a female expert in science, a strategy that enhances girls' confidence in science.)* "What do you think wildlife biologists care about?"

A chorus of students responded together, "Animals!" and "Wildlife!" Ms. G. continued, "So, in our woods, what would a wildlife biologist care about?" Kailey raised her hand to say, "Well, animals need food, and shelter, and they need safe places to hide." Kailey had written an effusive thank you letter to Ms. DeNotter. Ms. G. responded, "Kailey, on our walk today, as wildlife biologists, what might we look for?" Kailey thought for a second, and then said, "I think we will be looking for animal homes and what foods the animals eat out there." She looked over at Aurelia who nodded. (Practice: Planning and Carrying Out Investigations.) The class generated a list of animal foods and homes in the forest to write down in their science notebooks. The "food" list included nuts, berries, fungi, leaves, bugs for birds, and little animals; the "homes" list had nests, burrows, dens, holes in logs and rotten logs.

Ms. G. took out her oak tree picture and put it on the overhead. "Why might it be important to a wildlife biologist to know how many oak trees there are in our woods? Talk to the person next to you." (*Ms. G. carefully planned the partners and groupings in her class, an organizational structure that encourages participation for the girls in science.)* After the pairs of students talked, Ms. G. called on Grace and Megan. Megan deferred to Grace who had a little more outdoor experience, but rarely spoke. She responded, "Well, more oak trees would make more acorns for squirrels to eat."

"Nicely said!" Ms. G. was pleased. "Why do you think it might be important for a wildlife biologist to look up into the canopy and the understory as well as on the forest floor? Annika?" Annika had a big garden at home and also spent time hiking in the forest with her mom. She answered, "Because berries might be up there, or a nest or something, but down here you could find acorns or a hole in a log." Ms. G. responded, "Got it, thanks! Who else wants to add to Annika's response?"

Ms. G. put the hand-drawn map of the woods on the overhead projector and told the class, "Today we're going off the trail. We are going to be responsible for this section of our woods, looking at it as a wildlife biologist would…so let's all remember: we are looking for clues that tell us this is a good habitat, a good home for our wildlife."

Analyzing and interpreting data. After the students had collected and tallied observations of the woods, Ms. G. needed her students to become familiar with their data. Ms. G. placed her own large map on the whiteboard next to the three vocabulary words "*Quantity,* *Space, Time,"* and she showed the students how to explore the data. "We can look at the data we collected in different ways, 'quantitatively' or *how many* of a plant species there are, and 'spatially,' meaning *where* they are. Think about our walk in the woods and think about what things you noticed quantitatively and spatially about our woods." She paused, checking for responses, "I would like you to work with your partner and notice something spatial and something quantitative, and write it down in your science notebook. After you get one or two ideas on your paper, you can come up and write an 'observation' on the chart paper." (Practice: Analyzing and Interpreting Data.)

In a few minutes, Josh and Billy came to the front of the room and recorded their question on the chart paper: "*How come all the silver maples live around the pond*?" Aurelia and Kailey wrote, *"There are more box elders in the woods than any other trees." "There are HARDLY ANY black walnut trees – only 3 in the whole woods,"* came from another group. And Abby's group wrote, *"Most of the dogwood is in the center part of our woods."* Grace and Megan added, "*Mushrooms are everywhere!*"

Using modeling to define and refine an engineering problem. Next, Ms. G. took out the phenology wheel she had prepared for the lesson. Annika saw the wheel and whispered to a few others, "Phenology wheel!" She had loved the two phenology wheel activities Ms. G. had introduced previously: a class birthday activity and "enhancing a sense of place" sit spots. Ms. G.'s next goal was to make a model to explain the food availability using the phenology wheel.

Ms. G. stated, "We looked at our data spatially and quantitatively. Now we need to add the dimension of *time*. This phenology wheel is designed as a circular *calendar*, with a ring for each food type." She passed out a science folder for each pair of students that contained phenology observations from the woods from different years. "Using the past two years of phenology observations that we have along with your notes, we can determine the dates that these foods are available in our woods. We plan a color scheme that will tell the story of our data, and then we color the wheel that color on the months the food is in the woods. So if we do not color part of a ring, then it means *none of the* food can be found during that month. What kind of food do you think should go with the color green?"

Figuring out the data and accurate coloring the phenology wheel was a challenging undertaking and called for a lot of group collaboration. The partners circulated and shared the notes about the first and last dates a flower or leafy plant or fungi was observed in the woods. When it was finally finished, each student looked at the colorful wheel. The class was surprised at the results. Josh exclaimed, "Hey, you guys, look at all the white spaces!" Billy nodded knowingly, "You know what the white means; it's hard times." "Hard times! I know it," Josh answered. Kailey was distressed as she noted, "White is when they are hungry…" and then added, "Can we feed them?" (Practice: Asking Questions and Defining Problems.)

A discussion ensued about how to phrase the problem. The students thought that the problem should be stated as follows: "Problem: in some months, there might not be enough food (berries, nectar, leaves) for all the wildlife."

Multiple design solutions to an engineering problem. The class discussed two possible solutions right away. Annika thought they should put nuts and seeds out in the woods like she did in her yard in the winter for squirrels and cardinals. A few students agreed, but Billy reflected that a lot of animals buried the nuts. He thought the wheel should show the nuts were underground, and he didn't think nuts were the biggest worry. He pointed out animals eat different food in the winter, like deer eat bark and twigs when there are no more leaves. Josh reminded everyone that a lot of animals, like birds, depend on berries for food. He was troubled about there being no berries until July in the woods. (Practice: Engaging in Argument from Evidence.)

Grace offered to ask her parents to donate fruit and berries for the animals. Dubiously, Aurelia commented, "Ms. G., you have to feed them all the *time*. You can never forget or else…the animals depend on you to *bring* it. What will they do next year?" Aurelia looked at Grace, "When we are in 5th grade, even more animals will starve." Kailey carefully chose her words, "The wheel shows food from the woods – food that always grows in the woods. Can't we plant something that will always feed the animals in these months?" She indicated the white spaces on the wheel. "That would help the animals." (DCI: ETS1.A and ETS1.B Engineering Design.)

Ms. G. explained that changing a habitat to solve a problem is engineering design, called habitat management or restoration. She explained engineers use models, like the phenology wheel, to get a sharp look at their problem. They could use the phenology wheel to figure out what things in the habitat might need to change to provide for animals during the months when their food is not abundant. It is this feature, the phenology wheel's usefulness in defining the problem that makes it a model. Ms. G. helped the class to begin to think about habitat improvement by looking at each food ring. It was easy to see they couldn't do much about rain, snow, and the pond. Nor could they command the leaves to unfurl during the months when no leaves were out. Ms. G. instructed each pair to examine their phenology wheels and come up with some suggestions. (CCC: Cause and Effect.) *(Having students generate the problems and possible solutions that will drive class activities, an important scientific practice, is also very motivating for all students, including girls.)*

Abby immediately addressed the class when they reconvened: "What about flowers? Look at how they bloom only from April through June. A lot of insects need to eat nectar. Could our class do something about the flowers?" Annika, Abby's partner, said, "There are lots of flowers that grow after June, like in July and even in the fall in my mom's garden. We have lilies, and chrysanthemums, and sunflowers. We could plant those flowers in the woods, but my mom's garden has a lot of sun. Can they grow in our woods?" (Practice: Asking Questions and Defining Problems.)

Ms. G. commented that would be an important criterion if they made a decision to plant something in the woods. She wrote the word criterion and the definition on the board: "The information we need to have before choosing our solution." She made a grid on the white board. Under the heading "Possible Habitat Solutions" Ms. G. wrote: "*1. Plant—late flowering plant, food source: nectar.*" She made four columns under "criteria" and wrote, "Will it grow in our woodland?" in the first column. She left the next three columns blank. She explained they would be considering other important criteria for their engineering solution and writing them in the remaining columns with Ms. I.

Although Ms. G. loved the forest, she was a novice. So she found an expert who could answer her questions, Ms. I, the volunteer community naturalist. Ms. I. oversaw a weekly after-school club dedicated to doing activities to take care of the woods. *(The schools' after-school club represents a structural decision that positively impacts girls and their attitude toward science.)* Ms. G. encouraged all of her students to join. Recently the club had worked to remove garlic mustard, buckthorn, and honeysuckle. The club was well run and Ms. I. was well loved by staff and students.

Grace said, without being called on, “What do the bees do when the woods are all out of flowers?” Ms. G. smiled encouragingly. “Good question! I actually don’t know the answer.” She asked Grace to write the question down on the “Science questions” board by the word wall. She continued, “Annika and Abby wondered if there are some native late blooming woodland flowers and if planting those might be a great solution to our engineering problem. We will definitely have to do some research.” (DCI: 3-5 ETS1 Engineering Design.)

After the class looked carefully at the phenology wheel, they expanded their list to address their concerns. The list under “Habitat Solutions” expanded to include:

1. *Plant—late flowering plant, food source: nectar*
2. *Plant— early fruiting berry bushes, food source: berries*
3. *Plant—more black walnut trees, food source: nuts*

Coming up with the most important and appropriate criteria was more difficult, and Ms. G. invited Ms. I. to assist the class on this step. Ms. I. helped the students define five considerations to keep in mind as criteria for making their decision. With her guidance, the class modified the first criterion slightly and then added four new criteria to the grid:

1. *Will the plant grow in an oak-hickory forest?*
2. *Is it native?*
3. *Will it help wildlife?*
4. *Can we afford it?*
5. *Are there any negative effects from planting it?*

Ms. I. also suggested that the students research some plants according to their newly established criteria. She proposed that they could research three plants: the arrow-leaf aster, the serviceberry, and the black walnut tree. She said that although each plant was a potential solution to the problem, they needed to carefully consider all of the criteria before deciding on a solution. (CCC: Cause and Effect.)

After a week of researching native plant guides and websites and making a few calls to a plant nursery, the students evaluated each solution to the forest engineering problem. They developed a number system to rate how well each solution met the criteria. They could then evaluate the possible solutions, side by side, putting a number from 1 (does NOT meet this criterion) through 4 (meets this criterion well) in each space in the grid. The first criterion was, “Will the plant grow in an oak hickory forest?” (3-LS4 LS4.C: Adaptation.)

All three plants grew in this type of forest (criterion 1) and they were all native (criterion 2), so the remaining three criteria became most critical for deciding which species to plant. (Practice: Constructing Explanations and Designing Solutions.)

The serviceberry would feed the most species (insects, birds, chipmunks, and squirrels) during crucial times, because it produced flowers and berries in the slim months. Although the cost for this shrub was reasonable, it cost much more than the asters, so it was assigned a 2 for “Can we afford it?”

The black walnut was problematic. The students weren’t convinced the animals did not already have access to nuts year-round. Also, Abby and Annika found evidence that walnut trees produce chemicals that make it hard for some forest plants to grow.

Planting asters caused the least harm to the woods' floor because only small holes needed to be dug for their roots. However, asters wouldn't be able to feed as many species. The serviceberry got the most points, and the decision to plant serviceberry was just about unanimous.

Kailey was still unconvinced about serviceberry. She was sure that the asters were a better solution. She noted that some criteria mattered more to her than other criteria. (CCC: Influence of Science, Engineering and Technology on Society and the Natural World.) "They aren't all the same, you know? Me and Aurelia think that they should not be the same number of points. If we can only plant one serviceberry with our money, it won't be enough to make a real difference for the animals!" Aurelia chimed in, "Also, you know what else? We didn't give the asters points for feeding birds. It should be 3 points, because birds eat the insects." Annika changed her vote to asters and asked for another class vote. Their argument was convincing. The majority of the class voted to plant asters. (Practice: Engaging in Argument from Evidence.)

Ms. G.'s students were excited. They had used data to generate evidence, models to help them think, and engineering practices to solve a problem in the world around them. Through this process they had gained a deeper understanding of their woods, and as a result they had confidence in their decision. They were now engineers and scientists and ready to begin the engineering work of improving their woods.

NGSS Connections

Each NGSS performance expectation applies equal weight to the three dimensions of disciplinary core ideas, science and engineering practices, and crosscutting concepts.

3-5 Performance Expectations

3-5-ETS1-1 Engineering Design
Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time or cost.

3-5-ETS1-2 Engineering Design
Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-LS4 Biological Evolution: Unity and Diversity
Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all.

The class activities described in this vignette helped students make progress toward the performance expectations. In the vignette, the students blended core ideas about engineering with several different scientific practices, and applied an understanding of the crosscutting concept of how science, engineering, and technology influence society and the natural world.

Disciplinary Core Ideas

ETS1.A Defining and Delimitating Engineering Problems
Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the

basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.

ETS1.B Developing Possible Solutions
Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions.

At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs.

LS4.C Adaption
For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.

The unit focused on how engineering-based criteria can be developed, evaluated, and applied to improve a forest ecosystem. The students recognized the need for more information through more research and better understanding of science and engineering. Some students recognized the need to weigh criteria, which shaped the final engineered solution. With the teacher's guidance, students also recognized the importance of considering many possible solutions. They realized that their first ideas were not necessarily the best ideas. In order to come up with a solution, the students needed to gather evidence about different plant species and develop arguments that some species would more likely thrive in the habitat. The vignette illustrates how girls, along with boys, worked together to learn about their woods, to solve a problem by planting native species, and to recognize that they could help restore the environment through engineering practices.

Science and Engineering Practices

Asking Questions and Defining Problems
Define a simple design problem that can be solved through the development of an object, tool or process and includes several criteria for success and constraints on materials, time, or cost.

Analyzing and Interpreting Data
Analyze and interpret data to make sense of phenomena.

Constructing Explanations and Designing Solutions
Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the problem.

Engaging in Argument from Evidence
Construct an argument with evidence.

The students in the vignette engaged in many scientific and engineering practices, thereby building a comprehensive understanding of what it means to do science. This section, however, highlights engineering practices as part of performance expectations. *The Framework for K-12 Science Education* derives engineering practices from the steps engineers "engage in as part of their work" (National Research Council, 2011, pp. 3-5).

Engineering practices include *defining problems*. In addition to clearly stating the need to be met or goal to be reached, a problem definition must include a list of criteria or attributes of successful solutions and a list of constraints. The criteria usually include how a solution is expected to function along with which other features are desirable, whereas constraints tend to be the available materials, cost, or time. In this vignette, helping the students shift their understanding of the problem from feeding the animals to providing a long-term source of food was an example of this practice. It was also important for the students to investigate the forest—to research the problem—in order to better define it.

In *designing solutions* to a problem, it is common for children to jump at the first solution that comes to mind. However, it is often the case that the first solution is not the best. In the vignette, the phenology wheel was especially helpful in helping the students generate a feasible solution. A major point of this unit is the need to take time to generate a number of solutions and then consider each with respect to the criteria and constraints of the problem.

Crosscutting Concepts

Influence of Science, Engineering and Technology on Society and the Natural World
People's needs and wants change over time, as do their demands for new and improved technologies.

Engineers improve existing technologies or develop new ones to increase known risks, and meet societal demands.

Cause and Effect
Cause and effect relationships are routinely identified and used to explain change.

This unit highlights the idea that people can affect the natural environment in both positive and negative ways. In this vignette, the accent was on the positive, as students considered what changes they could make to improve the natural environment in order to better support the animals that lived there. It is important for the students to recognize that even though they were working with plants and animals, they were "engineering" the changes to solve the problem that they defined.

Common Core State Standards (CCSS) Connections to English Language Arts and Mathematics

The NGSS include connections to CCSS to reinforce the need for integration of English Language Arts (ELA) and math as part of the science curriculum. The vignette highlights the CCSS for ELA during science instruction:

- **SL.3.1** *Engage effectively in a range of collaborative discussions (one-on-one, in groups, teacher led) with diverse partners on grade 3 topics and texts, building on others' ideas and expressing their own clearly*.

The CCSS for math are also supported in Ms. G.'s science class:

- **3.MD.3** *Represent and interpret data*

Representation and interpretation of data is essential for accomplishing the task of collecting and applying data in the forest. The students are involved with the application of this standard when they use maps to collect information, create the phenology wheel, interpret the data, and argue for the necessity of engineering design.

Effective Strategies from Research Literature

The NGSS pave the way for increased exposure to all disciplines of science for all students. This is a breakthrough, in particular, for girls, as research attributes gender disparities in science achievement, college degrees, and careers to an early "experience gap" between girls and boys. The NGSS provide an opportunity for teachers to reach girls more effectively because girls perceive a disconnect between school science learning and science career goals (Baker, 2013). Research points to three main areas where schools can positively impact girls' achievement, confidence and affinity with science: (1) instructional strategies, (2) curricula, and (3) classroom and school structure (Baker, 2013; Scantlebury & Baker, 2007).

First, teachers can use instructional strategies to increase girls' science achievement and to strengthen their intentions to continue on in science. Such strategies include building opportunities to experience phenomena and framing science as inquiry. Girls respond well to strategies that integrate literacy with science. When teachers explicitly focus on metacognitive comprehension strategies, by using non-fiction texts in science class, girls' science learning and achievement is enhanced. Girls would gain confidence in classrooms where risk taking is encouraged, teachers would support positive messages about girls' competence, and it would clearly be conveyed that "science is for all."

Second, curricula can improve girls' achievement and confidence in science by promoting images of successful females in science. Schools can enhance girls' engagement in science by adopting curricula that focus on science topics related to the girls' interests. Similarly, girls develop aptitude and confidence toward nontraditional science topics when they are exposed to the topics early. For example, when girls have early exposure, they are more interested in computers and technology. Girls become more motivated toward technology if the curriculum incorporates design and stresses aesthetic aspects of science. In addition, girls respond to topics in physical and biological sciences that they perceive as addressing issues relevant to the real world.

Finally, research supports adjusting classrooms' and schools' organizational structures in ways that benefit girls. For example, after-school clubs, summer camps and mentoring programs enhance girls' confidence toward science and increase mastery of science content. Girls benefit from science and engineering activities that are intentionally designed to give active roles to all learners. This may occur through thoughtfully planned instructional grouping, pairing girls with friends, and giving every student her own materials to tinker with. Although placing girls in all-girl schools is not known to improve their science achievement, it is sometimes possible to improve results through all-girl groupings within classes containing boys and girls.

Context

Demographics

Nationwide, the total number of students in grades 1-12 of public charter and traditional public schools was approximately 49 million in 2009. Slightly less than half of those students, about 24 million, were female (National Center for Education Statistics [NCES], 2011a).

Science Achievement, Advanced Degrees, and Careers

Test scores in science achievement of female students lag behind those of males. According to the 2009 National Assessment of Educational Progress (NAEP), females received lower scores in science at the three grade levels tested: 4^{th}, 8^{th} and 12^{th} grades (NCES, 2011b). Girls were more likely than boys to have insufficient science credits necessary to accomplish mid-level or rigorous curriculum in high school (15% of girls, compared to 9% of boys, had insufficient credits). In addition, even when girls had the same level of class completion as their male counterparts, they received lower scores on the NAEP assessment. Girls who took standard science offerings in high school scored just slightly behind boys in the same classes, while girls taking high school courses at mid- and rigorous levels scored significantly lower than boys taking the same classes.

The research shows that the options for females to pursue science-related fields at the high school, college and career levels are progressively closed off (NCES, 2012). The trend begins in high school where females take more life science classes such as biology, environmental science, and health science technology and complete fewer advanced classes in physics, engineering science technologies, and computer science (NCES, 2008-2009). Throughout their high school experience, females opt for fewer mid-level and AP level courses, and therefore are less likely to meet requirements for an undergraduate science major.

Women have made steady progress since the 1960's in attaining undergraduate degrees, with women nowadays completing undergraduate programs at a higher rate than men (NCES, 2011a). However, women are far less likely to complete these degrees in technology, science and engineering fields. In 2010, women made up 58% of 2-year college students, but received just 15% of the Associate of Science degrees in engineering technologies (Milgram, 2011). In 2006, only 20% of students in physical science and engineering fields were female (National Science Board [NSB], 2006). Overall, women are significantly under-represented in engineering, technical, and computer science careers (NSB, 2006).

Educational Policy

In 1972, Congress passed Title IX, barring gender-based discrimination within federally funded educational programs. Recent policy to change the number of girls going into STEM careers includes the School to Work Opportunities Act, passed by Congress in 1994, to ensure the participation of female students in work transition programs (School-to-Work Opportunities Act of 1994. P.L. 103-239). More recently, President Obama pushed the "Educate to Innovate" campaign with the goal to "expand STEM education and career opportunities for under-represented groups including women and girls" (The White House, 2010).

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3-LS4 Biological Evolution: Unity and Diversity
3-5. Engineering Design

Students who demonstrate understanding can:

3-LS4-3. Construct and argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all.

3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time or cost.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Engaging in Argument from Evidence
Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s).
- Construct an argument with evidence.

Asking Questions and Defining Problems
Asking questions and defining problems in grades 3–5 builds from grades K–2 experiences and progresses to specifying qualitative relationships.
- Define a simple design problem that can be solved through the development of an object, tool or process and includes several criteria for success and constraints on materials, time, or cost.

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions.
- Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the problem.

Disciplinary Core Ideas

LS4.C: Adaptation
- For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.

ETS1.A: Defining Engineering Problems
- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account

ETS1.B: Developing Possible Solutions
- Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions.
- At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs.

Crosscutting Concepts

Cause and Effect
- Cause and effect relationships are routinely identified and used to explain change.

Influence of Science, Engineering and Technology on Society and the Natural World. (a)
- People's needs and wants change over time, as do their demands for new and improved technologies
- Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands.

CCSS Connections for English Language Arts and Mathematics
SL.3.1 *Engage effectively in a range of collaborative discussions (one-on-one, in groups, teacher led) with diverse partners on grade 3 topics and texts, building on others' ideas and expressing their own clearly*
3.MD.3 *Represent and interpret data*