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Human-Centered Design of Biotechnology: Where Will We Be without Bees?

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Introduction

Imagine you are teaching a lesson to your class. The students are engaged and paying attention. Suddenly, a bee flies in through the window and dances around the classroom. Students start screaming and arms are flailing as chaos erupts in your classroom. Bees evoke terror in children, but they serve a greater purpose; they are champion pollinators! Without bees, we would not have one-third of our global supply of food. Imagine life without coffee, apples, peaches, blueberries, tomatoes, avocados, cantaloupe, almonds, eggplants, peppers, and many more delicious and nutritious foods. The bees are in trouble right now, and we need to help them to survive!

Human Centered Design of Biotechnology: Where Will We Be without Bees? is a curriculum unit for upper elementary students focused on using design technology to engineer and model ecosystems. The curriculum unit will address the problem facing the world's most prolific pollinators: Bees. Nearly 60 years ago, Rachel Carson's book *The Silent Spring* was published and warned that pesticides and insecticides would lead to a silent spring without birds to sing. Due to her work, the pesticide, DDT was banned, and so far, birds continue to sing. However, Carson also warned of falls without pollination and fruit. A fruitless fall seems to be a real and imminent possibility. What will be the impact of a fruitless fall? The pollination problem and the impact it will have on humans and the environment is immense.

Demographics

My school, Mary Munford Elementary School, is in the west end of the city of Richmond, Virginia. It is currently the highest-performing elementary school in Richmond Public Schools. The students mostly come from middle-class homes with a lot of parental support, but there are also immigrants and students from low-income homes. My school also serves low-incidence autistic students. The range of skill level in fourth grade is huge. A few students barely speak English, some perform two years below grade-level, and other students perform at or above the 95th percentile on norm-referenced tests for reading and math. Many students enjoy science which is typically taught in a hands-on way at my school. In my experience, design technology and coding activities provide an opportunity for students who may not be the top academically to shine and gain self-confidence.

Rationale

There are several reasons why I am creating a curriculum unit about honey bees. First, it addresses a huge problem that not only affects beekeepers, but also all of humankind. The world is in trouble if we lose our most prolific pollinator. It will have devastating effects to the biosphere and to our food supply. The unit will provide a context for students to explore science in a way that develops connections and relationships that are natural and relevant across different learning objectives.

The second reason for this unit is that the new Virginia Standards of Learning for science will be fully implemented this year. The new standards include an overarching section entitled, “Science and Engineering Practices,” which is closely aligned to the design thinking process that is the focus of the Human Centered Design of Biotechnology seminar that Professor Anjelica Gonzalez is leading. The curriculum unit will address Virginia’s new (2018) “Science and Engineering Practices,” which seem to be aligned with the Next Generation Science Standards (NGSS) Science and Engineering Practices. Virginia’s Science and Engineering Practices address the engineering design process as well as computational thinking and the use of computers to create real and virtual artifacts.

Finally, when I conducted research about engineering and design in education, I found compelling information to support its incorporation in the classroom. The main idea of the book titled Invent to Learn: Making, Tinkering, and Engineering in the Classroom is, “Children should engage in tinkering and making because they are powerful ways to learn.”[1] The work of Montessori, Piaget, Papert, and Dewey resonates throughout the idea of making, tinkering, and engineering in the classroom. Tinkering is described as, “What happens when you try something you don’t quite know how to do, guided by whim, imagination, and curiosity.”[2] In today’s classrooms, the emphasis is placed on high-stakes testing, and we have moved away from best practices. The result is that most, if not all, of the fun has been removed from learning. I want this unit to excite my students, spark their creativity, and renew their love of learning!

Content Background

Parts of a Flower

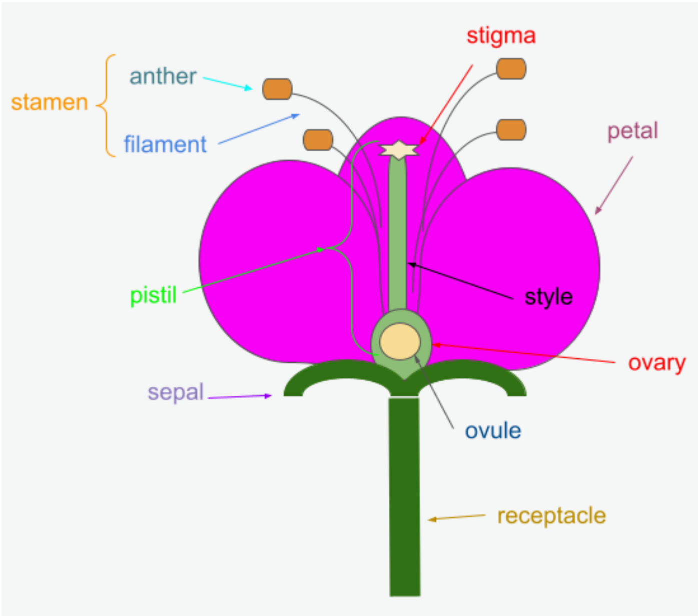

Figure 1: Parts of a Flower

Students need to understand the parts of a flower before they can understand pollination and the problems facing bees. Flowers are made up of many different parts (see figure 1) with distinct functions. The sepal is a green, leaf-like structure that envelopes a bud. Once the flower emerges, the petals are bright, colorful, and designed to attract pollinators. The receptacle is the part of the stem where the flower attaches and is thicker near the joint. The male part is called the stamen and it is composed of a filament, a stem-like appendage to which the anther is connected. The anther holds the pollen. The pistil is the female structure that consists of the stigma, the style, and the ovary. The stigma is the tip of the pistil and is sticky, so pollen will adhere to it. The style is a slim stalk that connects the stigma to the ovary. At the base of the pistil is the ovary, which contains ovules. Seeds form in the ovules upon fertilization.

Flowers come in many shapes and sizes. As a result the flowers' structures do not all look the same. Some flowers are incomplete, with only male or female parts, and others are complete, with both male and female parts.

Pollination

Once students understand the parts of a flower, they can explore pollination and how it occurs in flowering plants. Pollination is a process of transferring pollen grains from the anther to the stigma. Pollination is the way that flowering plants reproduce. Flowering plants can self-pollinate or use cross-pollination. Self-pollination occurs only in complete flowers, but cross-pollination can take place in complete or incomplete flowers. Flowering plants that use cross-pollination rely on outside entities to carry out pollination. Various insects, animals, water, and wind are some of the vectors that move pollen grains from one flower to another. Once pollen grains are moved to the sticky stigma of another flower the pollen grain may or may not germinate. If the grain germinates, it forms a pollen tube that descends the style to the ovary. Fertilization occurs when the sperm cell fuses with the egg inside an ovule. Following fertilization, a seed forms inside each ovule.

Why We Need Pollination

As stated in the introduction, about 70 percent of our food comes from animal pollinators. When one considers, "One bite out of every three we take is thanks to pollinators," it is worrisome, "but every bite isn't created equal either from a taste point of view or a nutritional one."[3] Upon further examination, 65% of global food production does not rely on animal pollination, as rice, wheat, and corn depend on wind pollination. That leaves 35%, which are dependent on pollinating animals.[4] Paige Embry further explains how many of our essential nutrients come from animal-pollinated plants, "Ninety-eight percent of the vitamin C, seventy percent of the vitamin A, fifty-five percent of the folic acid, and seventy-four percent of the lipids come from animal pollinated plants."[5] Realizing this, the disappearing pollinators are cause for much concern. According to Claire Kremen, a scientist as the University of California Berkeley, "If all the pollinators went extinct, we probably wouldn't starve," Kremen says. "But we'd all have scurvy or some other vitamin-deficiency disorder.”[6]

Bees Adaptations

Bees and flowers have coevolved over millions of years. They have a mutual relationship where flowers provide food (nectar and pollen) and bees help plants to reproduce by dispersing their pollen. Bees have developed different adaptations, both structural and behavioral, to gather and transport pollen more efficiently. Honey bees and bumblebees have a structure called corbiculae on their legs. The corbiculae act like a pollen basket. Bees wet the pollen with saliva and nectar to form a more compact package.[7] These “pollen pellets” are primarily used to feed developing bees. Other species of bees have a structure called scopa. This structure features elongated hairs on the hind legs. Still other bees have Megachilidae, which is essentially scopa on the underside of their abdomen. When bees fly a slightly positive static electric charge builds up that attracts the slightly negatively-charged pollen grains. Bees also use behavioral and structural adaptations within the hive. Bees create bee bread through a fermentation process. Bee bread is made by filling a honey comb cell about three-quarters full with pollen, then adding honey before capping the cell with wax. This process preserves the pollen for the future (see figure 2).

Figure 2: A frame of honey bees with bee bread

A Brief History

Pesticides and Herbicides

Humans have been innovating as long as they have existed. Through the many iterations and “improvements,” the effects seem to be more detrimental to our world. Humans have used pesticides to protect their crops from insects since ancient times. Sumerians and Egyptians used compounds and created pesticides. The Romans invented the first chemical weed killer.[8] The use of chemicals has only expanded as the world became more industrialized. In 1880, the first sprayer was invented and in 1921, the first aerial spraying dropped creosote over Ohio.[9] In 1935, DDT was invented to fight malaria-carrying mosquitos. DDT had a low toxicity to bees, but when it was banned, it was soon replaced with fenitrothion which was more harmful to bees.[10] More recently, neonicotinoids, a systemic insecticide, is the pesticide of choice, which seems to have debilitating effects on bees over multiple generations. These are all human-developed technologies invented with one goal in mind: extermination of a pest. Without the consideration of unexpected uses and consequences of these technologies, we find ourselves on the verge of real ecosystem modifications and extinction.

Beekeeping

Beekeeping has also changed over time. There are about 4,000 native species of bees in the United States and Canada.[11] Honey bees are not native to North America and were brought here by the colonists, first in 1622 to Virginia, then in 1639 to Massachusetts.[12] Soon honey bees were kept throughout the entire east coast. In the 1800’s, Lorenzo Lorrain Langstroth, a Yale alumnus known as the Father of Beekeeping, invented the movable frame hive that is still used throughout the world today. The Langstroth hive makes it possible to pull out a frame (see figure 3) without destroying the hive, thus eliminating the need for swarming bees. Apiculture, or beekeeping, has evolved over time and like everything else is driven by the almighty dollar.

Figure 3: A movable frame with a nice brood of honey bees

The Ancient Egyptians moved bees up and down the Nile River to pollinate various crops. The first record of renting bees for pollination in the United States was in 1910. The Honeybee Act of 1922 was passed to ban the importation of honeybees to prevent the spread of disease.

Bees

Native Bees (Wild Bees)

Native bees are a keystone species, meaning that they are critical to the food web. The survival of many other species depends on their survival. Of the 4,000 species of bees that are native to the United States and Canada, there are 456 native species in Virginia. None of the native species in North America or Canada are as organized and sophisticated as the honey bee.[13] However, native bees should not be overlooked! According to United States Geological Survey, "Native bees are estimated to pollinate 80 percent of the world's flowering plants."[14] Native bees fly at different times of day and some fly in bad weather. They carry pollen and touch the stigmas of flowers in different ways. Research suggests that small bees pollinate basal stigmas and larger bees pollinate apical stigmas. Pollination is more successful in strawberry flowers when both groups pollinate the flower.[15]

The book *Our Native Bees* mentions a large, worldwide study that categorized bees by size, sociality, and nest site. It compared pollination with a variety of species to a variety of types. The study concluded that a variety of types was more important than the variety of species. When the number of types of bees that visited an orchard increased from 1 to 4, the seed set (the number of seeds per pollinated flower) nearly tripled.[16] The use of native bees provides a variety of types and enhance pollination. Thus, it is beneficial to attract native bees to farms and orchards.

Bumblebees and other native bees use buzz pollination, a technique where the flower is vibrated to shake the pollen out of the flower. Honey bees do not know how to do it. Tomato, eggplant, blueberry and kiwi plants require buzz pollination. There are roughly 50 species of bumblebees in the United States, and they live in every terrestrial ecosystem in the nation.[17] There are 14 species of bumblebees in Virginia.[18] Many are in decline and the rust-patched bumblebee, native to Virginia, is considered endangered.

Blue orchard bees (*Osmia lignaria* or BOBs) are hard-working pollinators, who are not afraid to work in the rain unlike honey bees. Blue orchard bees are a type of mason bee and are more efficient pollinators than honey bees. "Six mason bees can pollinate an entire fruit tree; it would take 360 honey bees to pollinate the same tree."[19] The blue orchard bees are one type of mason bee. They nest in abandoned beetle tunnels, hollow stems, or holes in wood. They are called masons because they use mud to create separate cells in a tunnel for their young. Mason bees carry pollen on their bellies. Mason bees are not aggressive and do not sting!

Honey Bees

Honey bees were brought to North America from Europe. Commercial beekeepers raise honey bees for pollination. Today, honey bees are shipped all over the country on flatbed trucks. Commercial beekeepers follow the crops and the money. In February, they travel to California to pollinate almond trees. In March they move to Washington for the apples and in May they arrive in South Dakota for sunflowers and canola. Then they head east and reach Maine in June for blueberries and Pennsylvania for pumpkins in July. [20 As the number of honey bee hives has been declining and the crops requiring bee pollination have increased, it was necessary to waive The Honeybee Act in 2004 on an emergency basis. With the waiver, bees were flown in from Australia to reinforce the American hives.[21]

Problems the Bees Face

Politics

The problem facing pollinators is as complicated as it is controversial. Colony Collapse Disorder has ravaged the honey bee population and commercial industry. Researchers and beekeepers have proposed countless explanations, including the debunked claim that cell phone towers played a role in colony collapses. While naturally-occurring factors, such as viruses and insects, can cause harm to bees, man-made phenomena (e.g., pesticides, herbicides, transportation, etc.) can also be deadly to bees. This interference of man-made phenomena may be why the strife of honey bees has become political. Putting differing viewpoints aside, the problem facing pollinators must be addressed. Insects and their roles in the biosphere are intricately tied to food production, agricultural security, and human health. President Barack Obama's administration created the Pollinator Task Force, which issued the 2015 report National Strategy to Promote the Health of Honey Bees and Other Pollinators. The White House called for $82 million in federal funding to support pollinator health. While there are many possible explanations for the collapse, human impact seems to be an underlying cause for most, if not all, of the problems linked to the collapse of bees.

The Elusive Cause

Honey bees face a mountain of problems: varroa mites, hive beetles, Nosema fungus, wax moths, foulbrood, chalkbrood, stonebrood, Israeli acute paralysis virus (IAPV), deformed wing virus, Colony Collapse Disorder (CCD), poor diet, pesticides, stress and overwork, pesticides, and many more viruses. CCD is the greatest problem and mystery currently facing honeybees. CCD has devastated the honeybee industry. The cause of CCD has been elusive. As beekeepers and scientists try to determine the underlying cause of CCD, a variety of theories have been explored. One idea was that the timing of the CCD plague of 2006 – 2007 seemed to coincide with the waiver of the Honeybee Act and the bees that were imported from Australia and sent to pollinate the almonds in California. It appeared that Varroa mites were the culprit, but upon further investigation mite counts were no different in collapsed hives than in healthy hives. Besides, Varroa mites exist all over the globe except in Australia and Hawaii. Compounding the problem was the stigma of hive collapse, known among apiaries as PPB, or piss poor beekeeping, which caused gross underreporting of collapses. Whatever was going on even repelled the usual hive robbers from wax moth to bear.

In the winter of 2007, 30 billon bees died, and no one knew why.[22] Dennis vanEngelsdorp, Pennsylvania's state apiarist, examined some deadouts, or collapsed hives, and the remaining bees under a microscope. He noticed that the organs showed signs of rare fungal infection last reported about 50 years ago. VanEngelsdorp determined that the whole immune system of the bee had collapsed, similar to AIDS.[23]

VanEngelsdorp and other bee experts formed a group, the Colony Collapse Disorder Working Group at Penn State. The ideas for the cause vacillated from cell phone radiation to GMO food, to global warming. But, as each theory was closely examined, it was eliminated when evidence was contradictory. As the research went on, new theories emerged: Israeli acute paralysis virus (IAPV), fungus Nosema ceranae, and agricultural collapse disorder, and the impact of bee farming. These too were dismissed.

Evolution of Farming Practices

Prior to World War II, the United States had about 4.5 million beehives. In 2007, there were about 2 million beehives.[24] Changes to farming practices after World War II have greatly affected bees. Prior to the war, cover crops were used to improve the nutrients in the soil. After the war, farmers started using synthetic fertilizers followed by herbicides to kill the weeds. Many of the weeds that were killed were flowering plants that were needed for the survival of bees.

Monocultures

Farmers started growing monocultures, or fields of one crop, which over the years have become larger and larger. Farmers used to plant multiple crops to diversify their risk of a catastrophic loss. However, the federal government provides a safety net, which essentially encourages farmers to plant one crop. Monocultures are bad for the bees for several reasons. Monocultures provide a large food supply for a particular insect that feeds on the crop, which attracts the pests in large quantities. Thus pesticide use increases. Monocultures also create food deserts for bees since there is only one crop. The almond crop is a prime example. In 2020, it was estimated that 1.2 million acres in California were used to grow almonds.[25] The almond crop requires almost the entire bee population of the United States or about 2.4 million bee colonies, to pollinate it.[26] The bees are trucked in from across the country and following the almond bloom are trucked out since the area is flowerless. Since World War II, bees have been dying, yet the production of crops that require bee pollination has increased 300%.[27] Monoculture farms have been beneficial to farmers, but detrimental to the bees.

Pesticides

Pesticides are used commercially and residentially to control pests. In 2007, Americans spent $12 billion on pesticides or 850 million pounds! Sixty-six million pounds were used on homes and gardens. About 2/3 was used for agriculture and the rest was used by the government and commercial industry.[28]

Neonicotinoids is a potent class of pesticides. They are used for crops, turf, ornamentals, and on pets (control fleas). Acetamiprid, clothianidin, dinotefuran, imidacloprid, and thiamethoxam are the chemicals that are considered neonicotinoids. Farmers coat seeds in neonicotinoids. This class of pesticides is systemic and moves through the entire plant. When an insect takes a bite of a leaf, it gets a lethal dose. If a large amount is applied at the base of a plant, the pesticide can travel through the plant and get in the nectar and pollen. A large dose can cause a bee to twitch and die. The bees also can get a smaller dose when the seeds are coated. With a smaller dose, bees may appear to be intoxicated and disoriented. Bees also carry the pesticide-laden pollen back to the hive where it is used to feed brood (egg, larvae, pupa). The brood only eat in the larvae stage and are fed Royal jelly, which is comprised of pollen and a chemical produced by worker bees.

One theory that is still under consideration is sublethal doses of neonicotinoids, a class of pesticides. What are the long-term systemic effects of small doses over and over? This could be akin to smoking cigarettes every day. Studies from Italy, France, and the UK using an insecticide, imidacloprid, support this premise. The studies show that systemic long-term exposure to neonicotinoids is causing neurological impairments similar to Parkinson’s and Alzheimer disease that cause the honey bees to become disoriented and unable to find their way back to the hive. They die from exposure and seem to disappear. Recently there are reports and class action lawsuits cropping up claiming that Paraquat, an herbicide, is linked to Parkinson’s disease in humans. Honey bees are roughly 700,000 times smaller than the average human, so it is no wonder that these dangerous pesticides and herbicides may be killing massive amounts of honey bees and driving other predators away from the hives.

Human impact, whether from evolving farming practices, beekeeping practices, or loss of habitat, seemingly plays a role in every facet of the crisis. So, it is up to humankind to do what we can to remedy the situation and help the bees.

Possible Ways to Help

Regulation

In January 2020, the EPA came out with an interim decision to provide more guidance on the use of neonicotinoids. The EPA offers management suggestions to keep the pesticides on the intended target and to reduce the use on plants. The guidance also restricts applications when crops are in bloom to protect the bees. Though this will do little to help if the seed has been coated and the pesticide is already within the plant. The guidance suggests language on the packaging label that advises homeowners not to use the product. The last point is that imidacloprid, a widely used insecticide, cannot be sprayed on residential turf due to health concerns. The website also indicates that the EPA will work with the industry to develop management and stewardship practices.[29] Clearly neonicotinoids and the health risks to bees, humans, and the environment are on the radar and are beginning to be addressed.

Farming

Farmers use less herbicides and pesticides on their farms and adopt organic farming practices. One farming practice that would help the bees is to plant cover crops. Clover and alfalfa are highly nutritious for bees, but they are also beneficial in other ways. Cover crops reduce run-off, erosion, and the transport of fertilizers and pesticides to waterways. The use of cover crops fixes nitrogen in the soil which increases the natural nutrients and reduces the need for synthetic fertilizers. Cover crops also suppress weeds and may decrease the use of herbicides. Gabe Brown, a farmer in North Dakota, uses four different types of cover plants for the purpose of having live roots in the soil all year round. "Even a modest two or three species cover crop causes a 90 percent reduction in sediment runoff and a 50 percent reduction in fertilizer runoff into the watershed and sequesters a metric ton of carbon dioxide per acre."[30] In addition to helping the bees, cover crops provide other benefits for our environment.

Native Plants

Planting native plants is one of the most important ways to improve pollinator health. Native plants and animals have co-evolved. Therefore, native species of plants work well together and support one another. Native plants are not only important for pollinators, but for the entire ecosystem. Native plants invite plant-eating insects as well as their predators, and other organisms that fill niches in an ecosystem. Dr. Doug Tallamy, author of *Bringing Nature Home* sums up how native wildlife prefers native plants. He explains how a native oak supports 532 species of native caterpillars and a non-native Butterfly Bush only supports one species. Planting native plants will not only impact the bees, but also help the entire ecosystem!

Nesting Places

Native pollinators are attracted to native plants, but they also need a nesting place within their flying range (See Figure 4). Depending on the type of bee, the range can vary from a few hundred feet to a couple of miles. Bare patches of dirt, holes in wood, cracks in stone and concrete, and hollow stems are potential nesting sites. Some bees are ground nesters and others are cavity nesters. Honey bees are the only bees that build hives. It is helpful to the bees if some natural materials are in the yard.

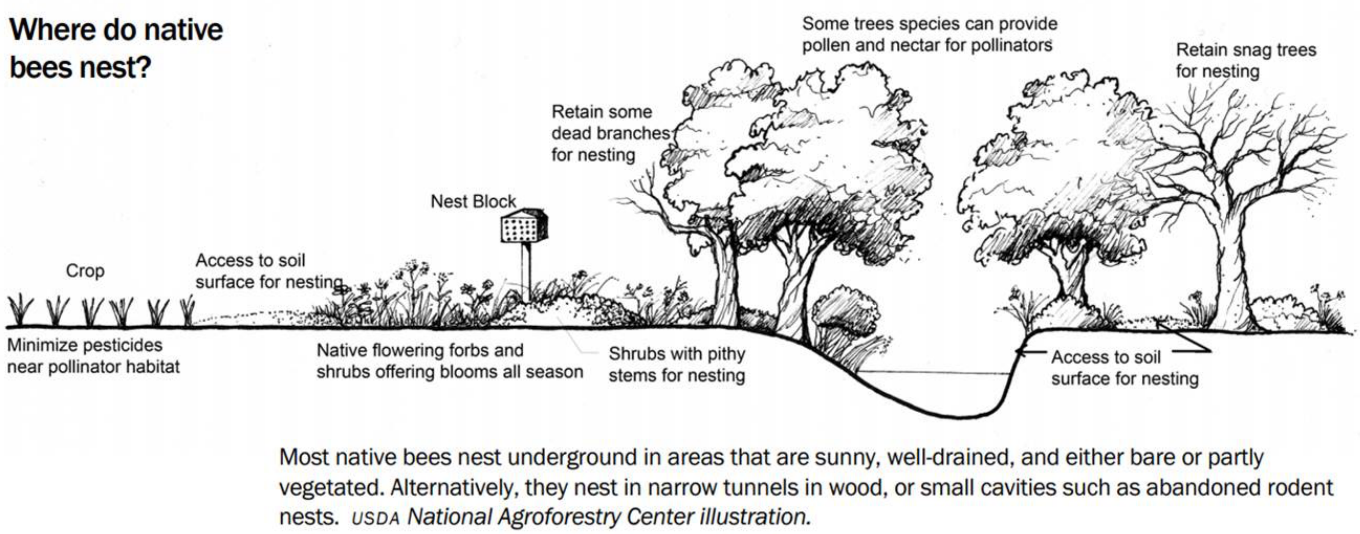

Figure 4: Where do native bees nest? Credit: Gary Bentrup, USDA National Agroforestry Center

Avoid Pesticides

People should avoid pesticides whenever possible. If they cannot be avoided, then people should do their best to choose a pesticide that is less harmful to the environment. The neonicotinoids are more potent and should not be used. Another solution to chemical pesticides is to purchase natural predators such as lady bugs or inspect and remove pests by hand.

Clover

Clover not only provides benefits as a cover crop, but also when it intermingles in lawns. When clover grows among grass, the grass is lusher and greener. This is because clover houses a bacteria in its roots that removes nitrogen from the air and turns it into a form that can be used by plants. A nitrogen-fixing legume, like clover, can provide most of the nitrogen grass needs if it occupies about 30% of the grassy area.[31] In addition to its nitrogen-fixing capabilities, clover also provides a food source for pollinators. Maybe a public relations campaign is needed so clover is recognized as a pollinator plant and not as a weed.

Design Thinking

The design process is a structure for problem solving and testing. The goal is to develop a solution that solves a societal problem, which may have multiple solutions. The Science and Engineering Practice in the Virginia Standards of Learning uses a model based on the National Aeronautics and Space Administration (NASA) engineering design model. There are eight steps which are: 1) Define (the problem), 2) Imagine (brainstorm a solution), 3) Research (research the problem and possible solutions), 4) Plan (a device to address the problem), 5) Build (a device to address the problem), 6) Test (to see if the device works), 7) Improve (the device), 8) Share (communicate results to stakeholders and public).

In the Human-Centered Design of Biotechnology seminar, Anjelica Gonzalez shared a five-step iterative process (See Figure 5). Both models are similar and both processes define the problem.

Figure 5: Design Thinking Iterative Steps by Stanford d.school and the updated 8 design abilities

In seminar, the use of a problem statement such as, “How might we help _____ to ______?” is recommended to clearly define the problem. The design thinking model uses Empathize instead of Research step. This is an important distinction as the work of the seminar is focused on *human-centereddesign* which takes into consideration the *need* and the *context*.

An example from seminar is when incubators for premature babies were brought to Malawi. Upon a subsequent visit the incubators were in a medical equipment graveyard. This was because the incubators broke, the parts were expensive, and people did not know how to fix them. The context of Malawi was not addressed. When the context was considered, the incubators were redesigned and made from car parts that were readily available, and the local mechanics were able to repair the newly designed incubators.

The design thinking process focuses more on interviewing as a method of research. The Imagine step is essentially the same as the Ideate step. The Plan and Build steps in the Virginia Standards are combined into one step, Prototype, in the design thinking model. Both models have Test as a step. The design thinking model fuses Test and Improve into one step. No matter which “steps” are followed, this is where the iterative process of test and improve are repeated until improvement is attained. The last step in the process in the Virginia Standards is Share. There is not a comparable step in the 5-step process, but the product would be shared, otherwise there is no sense in going through the process. The steps elucidated in Anjelica’s seminar are more concise and human-centered, but they are quite comparable.

Computer programming

Four decades ago, Seymour Papert, the Father of the Maker Movement, asked, “Why were computers being used by schools in such unimaginative ways?”[32] He also advocated for children to make things using computer programming. Papert and Cynthia Solomon, the co-creator of the Logo coding language, envisioned a school computer with many ports that would control lights, motors, and sensing devices.[33] Scratch is a version of Logo. Unfortunately, many schools continue to use computers in such unimaginative ways. A few years ago, I attended a session at a math/science conference about coding. I knew almost nothing about coding at the time. The session sparked my interest and connected me to other educators who were using Scratch, Makey Makey invention kits, and Hummingbird robotics kits. Since attending the conference, I attend regular Scratch Meetup sessions and have been learning and implementing these technologies into my classroom. The students love it!

Strategies

Workshops and Design Thinking

Students will be introduced to Design Thinking through a workshop model. The steps of the design process will be modeled and explored. The students will apply the Design Thinking process throughout the curriculum unit. Some of the activities will use an abbreviated version of Design Thinking. Other activities will require them to go through the entire process.

Computer Technologies

They will use Scratch coding, Makey Makey inventing kits, and Hummingbird robotics kits. This will be the students first time using these technologies, so the activities will grow in complexity as their skills develop.

Collaborative Groups

Ideally students will work in collaborative groups. This will allow them to help each other and talk through their ideas and iterations. Group work may be limited due to COVID-19 and the fact that elementary students are not yet eligible for a vaccine. A work around could be figured out using a virtual platform with breakout rooms and the online version of Scratch.

Guest Speakers

It is always nice to engage with members of the community. There is a beekeeper, and former parent, who will share his expertise about beekeeping with the class. Also, a nearby high school, Open High School, keeps bees. It may be possible to collaborate with some of the high school biology students who are involved with beekeeping as well.

Activities

Overview

My students will explore pollination and the multitude of problems bees are facing while they engage in the Design Thinking throughout the curriculum unit. My students will use Scratch coding, Makey Makey invention kit, and a Hummingbird robotics kit as well as craft materials (i.e. cardboard, paper, toilet paper rollers, pipe cleaners, etc.) throughout the curriculum unit. The creative design parts of the unit can be done without the technology component (Scratch and Hummingbird) and could instead use everyday materials.

First, we will learn about plant parts and how pollination occurs (objective 4.2). Then the students will learn about the problems plaguing bees, particularly the honey bee. There are many. Through the unit they will connect to objective 4.3, which explores ecosystems and human impact. I envision several small projects as my new fourth graders begin to learn how to use Scratch such as a diagram of the flower parts using the Makey Makey and the voice recording feature of Scratch to name the part and describe it. The students may make a landscape background and move a bee from flower to flower with Scratch. As the unit progresses the students will design a bee and make it move and buzz. For the culminating project, students will have to design a project using the iterative design process (empathize, define, ideate, prototype, and test) to develop a potential solution to the problem facing the bees. They can make an innovative product or a model of an ecosystem that illustrates positive human impact. Again, these projects can be completed without technology using arts and craft supplies. No matter what learning materials are used, the students will not only learn Design Thinking, but also processes (including the environment, signals, weather components, access to water, flora, and pollination) of bee survival, hive building/selection and pollination.

Day 1: Students will use Scratch and add a background landscape picture. They will add a “Sprite” of a bee and make the bee move from flower to flower with the “glide” block.

Day 2-3: The students will make a drawing of a flower and label the parts. Then they will add brad fasteners to the parts of the flower and use a Makey Makey and Scratch so that when the Makey Makey alligator clip touches the brad, a voice recording of the name of the part and the function will play.

Day 4: The students will engage in an inquiry lesson about pollination. Students will use microscopes, prepare slides, and observe how a grain of pollen germinates. The students will have to make observations and try to figure out what is happening. https://www.youtube.com/watch?v=Su6fxJQ5q3o

Day 5: The students will view a Google Slide with a picture of an ecosystem. They will have to circle the living and non-living pollinators in the landscape scene.

Day 6: The teacher will provide flowers that the students will dissect to identify the different parts.

Day 7: The teacher will explain the pollination process. The students will use Design Thinking to design a 3D flower using craft supplies. The model will have to include the pollen tube and seeds in the ovule (see suggested materials list).

Day 8: Students will work through the Design Thinking and create a prototype of their pollinated flower that forms seeds.

Day 9: Students will write an explanation of the pollination process.

Day 10: The teacher will provide instruction about the different types of native bees.

Day 11: A local beekeeper will visit and tell the students about honey bees. The students will complete a Venn Diagram comparing and contrasting honey bees and native bees.

Day 12 -15: The students will use Scratch and the Hummingbird robotics kits to create a bee that moves. It should also buzz or vibrate (bumble bee).

Day 16: The class will go out and assess the school yard for potential areas to create a pollinator area. Once they locate an area, they will look for food sources, nesting materials, and count any pollinators.

Day 17: Students will select that name/position of the person their group will interview. Then they will develop questions to ask in the interview

Day 18: Interview people via Zoom for 15 minutes. Then the class will jigsaw and share the information from each interview. Interviewees will include the principal, the parent in charge of playground clean-up, a local master gardener, a member of the Department of Conservation and Recreation (DCR).

Days 19 – 23: Students will design their ecosystem

Days 24-25: Students will share their ecosystem

Days 26-30: The class will go into the school yard to the area that they previously assessed. With support from parent volunteers, will create pollinator gardens to attract blue orchard bees (BOBS) which are wonderful pollinators and do not sting. They will include aspects from the ecosystem that they designed to help the bees. Later in the spring students will conduct data collection to count the pollinators to see if their work was beneficial for the bees.

Activity 1: Design a Pollinated Flower

Students will use the Design Thinking Process to create a 3D model of a flower (Day 7) while working in small groups (if permitted with COVID). They will include all the parts of the flower, the pollen tube, and seeds in the ovule. Materials will be provided including cupcake pipettes that when the bulb is cut off will look like an ovule and can hold beans that may be used to represent the seeds. Students may come up with different ways to represent the parts of the flower, that is a part of the Design Thinking Process.

Activity 2: Design a Bee

On Days 12-15 students will design and create a bee using craft supplies. If available, the students will use Scratch, Makey Makey invention kits, and a Hummingbird robotics kit to make the bee move and buzz. If the technology is not available, students can make a simple circuit with a buzzer, and create a lever or a pop-up style way to make the bee move.

Activity 3: Culminating Activity

The culminating activity has multiple parts and takes place from Days 19- 30. The students will have to use the design thinking process to create an ideal ecosystem for bees that includes their innovations for positive human impact to help the bees. The students can use either a cookie sheet or a cafeteria tray as the base for their ecosystem. They will use the craft materials to engineer it. They may wish to use Scratch coding, Makey Makey invention kits and the Hummingbird robotics kit.

Once the ecosystems are designed the students will make a presentation including a media message to promote ways to help bees.

The final part will be to bring their design thinking to the real world by improving an area of the school yard to attract Blue Orchard Bees.

Materials for Classroom Use

The following materials are for all of the classroom activities listed, but the list is not inclusive. The technology is included in the list but is not necessary. Cupcake pipettes (use bulb for ovules), Pipe cleaners, colored foam, cardboard, cardstock, straws, balloons, white beans, construction paper, brads, florist foam, clay, compound microscopes if available (or an overhead microscope), microscope slides, cover slips (for slide preparation), pipettes, glass stirrer, distilled water, potassium nitrate, magnesium sulphate, boric acid, sugar, flowers with visible stamen and pistils, Makey Makey invention kits (4-5), and Hummingbird robotics kits (2 class sets).

Resources for Teachers

https://www.youtube.com/watch?v=Su6fxJQ5q3o

https://www.ted.com/talks/louie_schwartzberg_the_hidden_beauty_of_pollination/transcript?language=en

https://www.ted.com/talks/dennis_vanengelsdorp_a_plea_for_bees

https://www.ted.com/talks/marla_spivak_why_bees_are_disappearing?language=en

Appendix on Implementing District Standards

Science Standards of Learning (SOL)

SOL 4.1 is new in the 2018 standards. The engineering practices are to be woven through the content and taught all year long. The engineering practices are designed to apply science skills to solve a problem or to make a prototype for an object, tool, process, or system. Computational thinking involves using a computer to make the prototype. All of the activities involve Scratch coding, Makey Makey invention kits, and the Hummingbird robotics kits implement the engineering practices and computational thinking.

SOL 4.2 is a Living Systems and Processes standard. It specifically speaks to the structures of plants and animals that play a key role in their survival. Pollination and reproduction of plants are a part of this standard and the crux of this curriculum unit.

SOL 4.3 is another Living Systems and Processes standard. This standard focuses on ecosystems and human impact. The plight of the bees is a direct result of the actions of humans. The decline and potential extinction of bees will affect not only ecosystems, but the biosphere.

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Notes

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