Disasters: Nature's Idea of Selection

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Introduction

St. Georges Technical High School is one of four public vocational-technical high schools in New Castle County, Delaware. The students are representative of diverse backgrounds – urban Wilmington, suburban Newark, and rural Middletown. The unique draw for a technical high school like ours is the ability for students to study a trade and graduate with a certification or licensure in a career pathway. Our students apply to St. Georges for a variety of reasons: learn a family trade, learn in a safer school environment when compared with other public high schools, or earn a certification to join the workforce instead of continuing on to a post-secondary school. With each graduating class, approximately fifty percent of students directly join the workforce, an apprenticeship, or trade school. The remaining fifty percent continue on to a four-year college/university, or a branch of the military.

The technical school environment offers students a distinctive high school experience. Each student earns a certificate or license in their field of study upon graduation. The trades offered to our students are as diverse as the students themselves; ranging from nursing to carpentry, web design to culinary, automotive technology to early childhood education, and a dozen other options. In the school year 2018—2019, out of 872 upperclassmen (sophomores, juniors, and seniors), 20% study a trade in the Public/Consumer Services cluster, 23% study a Construction trade, 35% study in the Health Career cluster, and 23% study in the Business and Technology cluster.

St. Georges, a technical trade school, is considered a branch of the public-school system. Therefore, students have access to their career classes in addition to the state-mandated academic courses offered within St. Georges. I am one of the science instructors within the building; teaching biology to sophomores. This unit has been developed for tenth-grade biology, a required course for graduation by the state of Delaware. The topics covered in this course are as follows: ecology, genetics, and evolution. This unit is intended to be incorporated into the evolution section of the course and can be refrenced throughout other sections in the genetics unit.

As a fully-inclusive school, students of all ability levels, both regular education and special education students, are placed in the same class and therefore it becomes important for the instructor to be able to differentiate each lesson. Following the blended learning educational model, this unit provides students with several choices in how they learn, express their knowledge, the pace at which they learn, and utilize technology to enhance their overall learning experience. Within the blended model, the teacher becomes a facilitator while the student becomes the gatherer and organizer of information. My role as a facilitator is to provide students with appropriate resources and experiences to extract information and scaffold the lesson. It is important that the teacher carefully identifies multiple resources for gathering information to address kinesthetic learners, auditory learners, and oral learners.

The state of Delaware has adopted the Next Generation Science Standards (NGSS) and is currently implementing them into the high schools. There has been an increase in the number of standards taught in tenth-grade biology; therefore, the depth of knowledge able to be reached is limited. The goal is to increase student engagement and motivation into their own learning through the exploration of skills. Beginning with a phenomenon, students create their own questions, cultivating their own interest in Biology. The main skills assessed in this unit are engineering and supporting claims using evidence.

Rationale

This unit is designed to integrate natural selection and disaster science with the school-wide focus on literacy. Literacy includes the skills of reading, writing, speaking, and listening. The unit is taught during the evolution section of the Biology course occurring as the last third of the course – ecology, cells, and genetics are taught prior. We study how disasters, both man-made and natural, impact the mortality and success of various species. Students are able to determine which variety of phenotypic characteristics are favorable during changing conditions. Students apply this knowledge to various scenarios and support their claims with quantitative and qualitative evidence in written and oral expression. Real-world case studies allow students to utilize the concept of natural selection in a tangible way.

The newly adopted science standards require students to apply interdisciplinary skills to a scientific idea and to coherently explain their rationale using evidence. In response to the shift in standards, the goal of the unit is for students to understand nature’s response to environmental change through the use of case studies, simulations, mathematical models, and written and oral summary. Disasters influencing natural selection provides students multiple opportunities to incorporate writing skills and mathematical concepts with past, current, and future biological impacts. The use of case studies enables students to experience a real-world scenario from the past or present to better grasp that species change over time in response to their surroundings, and how variation within a population is required for the survival of the species. Students are able to apply statistics and probability to support explanations that organisms with an advantageous trait increase in proportion compared to organisms lacking this trait in a given environment. With a general understanding of natural selection in action and with the skill to apply statistics and probability to the situation, students are able to take a hypothetical disaster setting and predict the impacts on the local ecosystem.

One potentially problematic portion of the unit is the students' understanding of mathematical concepts, specifically statistics and probability, and the ability to apply these models to other scenarios outside of math class. Depending on the current math course taken by the student, a supplemental lesson on these skills would prove helpful. One way to overcome this hurdle would be to connect with the math teachers and develop a joint lesson to address the content. For my students, this obstacle would not apply to all of my classes. Some students are in the advanced math course or took their math course prior to Biology because we work in semesters; however, for those who are behind or have not yet taken math for the year, these students would benefit from a supplemental unit.

As a result of completing the curriculum unit, students have the ability to explain using evidence how ecosystems and populations respond to changes in their environment. Students are able to draw upon activities, labs, mathematical models, and research to support the idea of natural selection as an evolutionary process. Peers have the opportunity to experience multiple realistic and fictitious scenarios where the environment has changed due to human activity and natural causes and how different populations either thrive or deteriorate in frequency. Given different scenarios, students analyze the potential impact of the disaster and evaluate the changes to the local populations through a visual assignment that is presented to the class. Students learn through a gallery walk-style lesson developed by peer collaboration. By the end of the unit, students have a greater understanding of natural selection as it applies to current conditions and are able to apply it to future disaster scenarios in other ecosystems.

Content Objectives

With the completion of this unit, students will be able to:

- Explain using evidence how disasters influence natural selection leading to adaptations in a population.
- Mathematically explain how some populations flourish while others decline after a disastrous event.
- Explain using evidence how environmental changes can cause an increase or decrease in populations.

Background

Prior Knowledge

Students have been introduced to the evolution unit through the creation of a timeline based upon a class reading incorporating relevant naturalists, geologists, and scientists throughout history. Charles Darwin is referenced for his work aboard the HMS Beagle and his authorship of, *The Origin of Species by Means of Natural Selection*. Prior to Darwin's research, most citizens of England believed that each species was a divine creation. This implies that each organism remains in the form it was originally created and cannot be changed. Preceding Darwin's study of species, Jean-Baptist Lamarck believed evolution occurred through the use and disuse of an individual's physical features. He believed it was the instigator action of the environment on the needs and habits of an individual which adapts and modifies organs, allowing for the simplest lifeforms to spontaneously generate characteristics of vertebrate mammals.[1] Lamarck believed an individual could transform and enhance itself, whereas Darwin believed the population's visible heritable traits could shift over the course of generations. Lamarck's and Darwin's ideas both recognize that species change in response to an environment, however their ideas on how this modification takes place is quite different. Both men also supported the idea that all organisms were descendants of a common ancestor. Influencing Darwin's theory, Charles Lyell's book, *Principles of Geology*, focuses on how the earth had changed over the course of history. Darwin agreed with Lyell's assessment on formation of the Canary Islands; where the earth balanced its movements through compensation.[2] The concept of a moving and shifting earth would eventually influence Darwin's ideas when visiting locations around the world. The course acknowledges Alfred Wallace's contribution to natural selection because he independently came to a similar conclusion although credit is given to Charles Darwin.

Natural Selection

Charles Darwin is most famous for developing the theory of natural selection while aboard a round-the-world voyage on the HMS Beagle where he visited the Galapagos Islands, off the coast of Ecuador. Aboard his journey on the HMS Beagle, Darwin observed and documented evidence of evolution at multiple locations. While in Uruguay in November of 1832, Darwin focused primarily on the geographical distribution of birds, as well as the physical and behavioral similarities between seemingly distant species.[3] The physical similarities between species eventually led Darwin to the conclusion that species have a common ancestor supporting his notion of decent with modification; changes to a species had taken place over many generations. This reinforces the idea of advantageous heritable traits being passed on to offspring. On his visit to Buenos Aires, Argentina, Darwin discovered various fossils – giant fossil armadillos resembling the modern-day species and a long-necked pachyderm fossil resembled a camel with the neck of a giraffe.[4] Darwin began seeing connections between fossils and modern-day species. Charles Lyell's book on how the earth had changed over time corresponded with Darwin's observations in Chile. Charles Darwin explored both the eastern and western sides of the Andes mountains that run through Chile. He noticed that although the climate and soil conditions were similar, there were considerable differences in the plant species living on either side of the mountain range.[5] Furthermore, Darwin observed thirteen species of mice on the eastern side, but only five species on the western side, with no resemblance between them.[6] These differences in mice species proved that geographical barriers could prevent the reproduction between species. Another geographical barrier that Darwin witnessed were the various species of finches on the Galapagos Islands. After his visit to the Galapagos, Darwin concluded that it was the distance and isolation between islands that allowed the finch species to develop independently of each other, noticeably in the shape and size of their beak.[7] He linked the variation in the beaks to the differences in lifestyle and feeding habits.[8] This is his most recognizable contribution in addition to his book, *The Origin of Species by Means of Natural Selection*.

Natural selection suggests nature is able to select the most favorable heritable traits for inhabiting and surviving a particular environment, allowing certain individuals to reproduce and pass on these traits to their offspring. Students previously studied DNA structure and function, the cell cycle, sexual reproduction, and mutations in class. They understand that through sexual reproduction and potential mutations, variations arise among individuals. This is explained through the concept that the student and their sibling are not identical due to independent assortment and variation among parents. The application of DNA and genetics into the evolution unit is pivotal to students' comprehension of the theory of natural selection. The DNA determines an individual's characteristics, but the environment will determine whether those traits will provide an advantage to the individual to reproduce more successfully.

There are four main components, or principles, to support the theory of natural selection: variation among individuals, overproduction of potential offspring, competition between individuals over resources, and differential survival and reproduction. Variation of traits among a population of a given species allows for the success of some individuals compared to its peers. The variation may come in many different forms – color, size, and markings, to name a few. Depending on the climate of the region or potential disaster within the region, the advantageous trait could differ as the environment changes. The longer the period of stability in the environment, the amount of variation will decrease, favoring the most desirable trait. In an unstable or mobile environment, the number of potential varieties within a population is likely to remain diverse. Variation allows for fluidity within a population, increasing the potential for its overall success and survival.

Organisms tend to produce more offspring than the environment can support, to increase the likelihood that one or more offspring will mature and reproduce. Thomas Malthus' work, *Essay on the Principle of Population,* discusses if the human population grew more quickly than food could be produced, it would create competition within the community.[9] In the case of humans, food would be considered a limiting factor or resource. Darwin was able to apply this concept to natural selection because only those individuals with the most suitable traits in an over-populated habitat will be able to outcompete peers to survive to maturity and reproduce. He noticed that every organism had the ability to over-populate, yet population numbers remained stable. For example, a bell pepper produces over a hundred seeds in each individual fruit, or a human male producing millions of sperm in hopes that one will reach an egg. If every seed, sperm, or egg reached maturity, there are physically not enough resources on Earth to support all of the individuals. So why would an individual allocate enormous amounts of energy on producing so many potential offspring? Nature knows that not every individual will mature, and for the few that do reach maturity, it is not a guarantee that they will reproduce or reproduce successfully.

Competition is by definition the struggle for survival, and among individuals of a population, competition is inevitable where there is a finite amount of resources. Darwin deduced within competition, the suitability of particular characteristics to an environment and limitations on available resources ensure the automatic sorting of individuals that carry useful variations which improve adaptation, whereby eliminating individuals that lack this variation.[10] Some resources individuals compete over include, food, water, shelter or territory, mates, and dominance within a hierarchy. In addition to traditional competition, the struggle for survival would also include avoiding predators. It is not always the strongest individuals who gain the advantage; it could be the individual with the best camouflage that will access the most food or avoid predators. There are instances where the more cunning individual out-competes other members of the species. Success is measured by the number of offspring produced who reach maturity – survival of the fittest. It is important to reinforce to students that the term fittest in this sense is not based on strength, but a factor of successful reproduction.

Differential reproduction is the increase in frequency of traits in a population allowing individuals to live long enough to reproduce, passing on their traits to the next generation. These traits typically are ones that provide an individual an advantage. Adaptability inherently leads to more reproduction for the individual. The increased number of times and individual can pass along its traits, the frequency of the trait will increase within the population. This is supported by the organisms producing more offspring than the environment can support, with the goal to have at least one offspring reach maturity to continue passing on the traits. Variety within the population also increases the probability of a sustainable population.

Human Impact

The exploitation of many animal and plant species for human harvest is not random and has brought about genetic changes in these populations. In agriculture, the goal of human influence is to increase the frequency of desirable phenotypes; by contrast, hunting and fishing decrease the traits once seen as favorable in the wild population.[11] For example, the frequency of tusk-less elephants in Zambia has increased from 10% to 38% due to the poaching of elephants with tusks for ivory.[12] If the elephants with tusks are killed or disfigured prior to mating, the potential for the tusk trait to be passed to offspring significantly decreases. Ironically, Darwin was a hunter; he understood that removing desirable animals by hunting would decrease the frequency of those particular traits but did not discuss the evolutionary consequences and how they might impact natural selection.[13] Humans have been modifying crops for centuries, from selective breeding, before genes and alleles were understood, to more current practices of genetically engineering characteristics of food crops. We have the ability to choose and proliferate characteristics of other organisms that can benefit the needs of humans. Unfortunately, at this point in history most of the modifications influenced by humans have permanently shifted the genetic pool for many species; other species have the potential to recover if sustainable practices are put into place.

Climate change is driving natural selection and the favorable variations that exist among populations. Some species may undergo range shift, or permanent migration, to avoid potential extinction, other species may have the flexibility to undergo adaptive evolution in response to the selection based on climate.[14] Which option occurs for a given species will depend on the plasticity of genetic adaptability and the speed at which these changes transpire. The more rapid the changes in climate occur, selection might result in extinction rather than adaptive evolution.[15] The measured changes in precipitation around the globe have the greatest impact on selection when compared to temperature and spatial analyses.[16] The plant and animal populations most impacted by climate change and the redistribution of precipitation are those at northern latitudes.[17] Plants are at a disadvantage because of the limitations on migration. Arctic, alpine, and island species are labeled as having 'nowhere to go' because there is no migration option for these species.[18] Decreasing the amount of space in cool and cold climates year-round will reject the varieties most suited for this type of climate. Also, at a disadvantage, are those species with long life history patterns who are slow to reproduce and disperse seeds after reaching maturity.[19] If these species are unable to proliferate in a changing environment, this could exacerbate the problem by having fewer trees on the globe to absorb carbon dioxide from the atmosphere for photosynthesis where it stores the carbon in the form of glucose.

Case Studies for the Instructor

The following scenarios on peppered moths and Galapagos finches are used throughout the unit and in many textbooks. Teachers should find it beneficial to have additional knowledge on these in comparison to the smaller examples in the next section.

Peppered Moths

The case of the peppered moths is one of the most famous examples of natural selection as influenced by humans. The case study that is studied in the classroom, illustrates an English society prior to the Industrial Revolution where there were two color varieties of peppered moths – light and dark – with a significantly larger light-colored population. However, during England's Industrial Revolution, much of the soot from the factories coated the light-barked trees, creating the appearance of darker trees. An increase in the dark-colored peppered moths was recorded, supposedly due to the change in the environment. Predaceous birds more easily noticed, and as a result, caught and ate, the light-colored moths because they no longer camouflaged against the darkening tree bark. This led to the change in gene frequency of the peppered moth population in England – there was an increase in the dark gene and a decrease in the light variety. In the 1950s, Kettlewell conducted a capture and release experiment in both polluted and unpolluted forests, concluding that light moths had the advantage in unpolluted forests and dark moths had the advantage in polluted forests.[20]

A more recent account of this change in species population due to human activity has been recorded in Detroit, Michigan. As a result of the Clean Air Acts improving air quality near industrialized areas, the light-colored moths were increasing the number of individuals in the population.[21] In 1960, dark moths accounted for ninety percent of the peppered moth population, but in 1994, dark moths only made up twenty percent of the population.[22] This reversal of the dominant variety in a location brought upon by a second impact by humans, reinforces the fluidity of genetic favorability and the importance for variation within a population.

Ironically, the peppered moth case study that appears as a classic example of natural selection, and has been used in classrooms for decades, might not be completely true. In the mid-1980s it was discovered that peppered moths were nocturnal creatures and the color did not impact whether the birds noticed them stationary against the tree bark.[23] In order to continue to use the peppered moths as an example in the classroom, it now should be tied in to the scientific method at work. Students should understand that the re-testing of an experiment is important to verify results. Persistent research may illuminate a different result and all results must be taken into account.

Galapagos finches

While Charles Darwin visited the Galapagos Islands in late 1835, he devoted much of his attention to reptiles and birds.[24] The finch population variations are one of Darwin’s most recognizable contributions to the theory of natural selection. He noticed the finches differed in the size and shape of their beaks. Each beak size and shape specialized in attaining different food sources. It was not until 1837 that Darwin realized the variations among finches were not variety of a single species, but different species completely.[25] Being from different species indicates a large enough genetic difference and losing the ability to interbreed over millions of years.

Three factors explain the multiple species of finches; natural selection, diversification on separate islands, and competition between species for food.[26] In each unique environment, specific characteristics become more prevalent as those individuals mature and reproduce. Not all of the individuals from the mainland would have survived the journey to the islands and others would have struggled in the new conditions.[27] Nature is selecting for the most suitable traits for individuals to survive in the unknown environment. Those that survive are able to pass down these traits to their offspring. As the population grows, it becomes better adapted to the environment. The colonizing finches would have dispersed across the many islands, members who did not interbreed would eventually be categorized as two individual species. Over thousands of years, Daphne Island became increasingly isolated from the surrounding islands due to sea level rise from glacial ice.[28] Responding to competition, some individuals had adaptations allowing them to eat a different type of seed or insect. These individuals eventually became separate species. A shorter, bulkier beak would benefit a population of seed-eaters that require force to open a seed case, compared to a thin needle-like beak that would benefit a population grabbing insects from inside trees.

One specific example of evolution within the finch populations is illustrated by the changes in *G. fortis*' (a type of finch species) beak size over a forty-year time period; increasing in 1978 and decreasing in 2005.[29] There are two explanations for the change in beak size. In 1978, a hybrid species from neighboring Santa Cruz Island took refuge on Daphne Island forcing the beak size to become larger to avoid niche competition, while in 1982, the introduction of the Large Ground Finch (*G. magnirostris*) favored a smaller beak size in *G. fortis*.[30] The shift in beak size has been influenced by periods of drought or excessive rain on the islands throughout history. Genetic variety is extremely important in having an adaptable population. The less ability to adapt, the less likely survival might be with an introduced species.

Case Studies for the Students

This section addresses simple scenarios students are working with during the fourth activity. Instructors do not need additional information beyond what they provide the students because the students are only using these to identify the variation within the population, the competition or struggle for survival, the environment, and which trait has the genetic advantage.

Pesticides and Mosquitos

When the pesticide DDT was first used a half century ago to kill mosquitoes and other insects, it was very effective in controlling their populations. Most of the mosquitos were not resistant to pesticides but a small number of mosquitos had a genetic mutation where they were not harmed by this pesticide. Today, even large doses of DDT are ineffective (don't work) in controlling mosquitos and many other insect populations. Explain why there are so many more mosquitos around.

Ugandan Elephants

The tusks on an elephant are actually modified teeth and help the animals to strip bark off trees, dig for food, defend themselves and find mates. Normally, African elephants, male and female, have tusks. In 1930, only 1 percent of the elephant population in Queen Elizabeth National Park was tuskless because of a rare genetic mutation. In the 1970s, a civil war began in Uganda. Poachers illegally killed elephants for their ivory tusks. By 1992, the elephant population had dropped to about 200 followed by an increase to 1,200 individuals in 1998 due to the ban on poaching. A survey in 1998 revealed that as many as 30 percent of the adult elephants did not have tusks.

Sickle-cell Anemia

Sickle-cell anemia is a disease that changes the shape of red blood cells and is caused by a mutation. People with sickle-cell anemia are born immune to malaria, an infection caused by the bite from a mosquito. Malaria is wide spread in Africa and most people in Africa have sickle-cell anemia. Use your knowledge of natural selection to explain why most people in Africa have the sickle-cell trait.

Galapagos Tortoises

Tortoises eat plants. The neck length of tortoises varies island to island in the Galapagos and the plants on each island are unique and come in different heights. Some have short necks that can only reach grasses, others can reach short flowering plants a foot off the ground, and others able to reach taller plants that reach above their shell. On Isabela Island the plants grow very close to the ground and there seem to be a higher population of tortoises with very short necks. Explain why most of the tortoises on Isabela Island have short necks instead of a longer one.

Rock Pocket Mice

Rock pocket mice live in the deserts of the American southwest. Ancestral pocket mice had light-colored coats that blended in with the region's rocks and sandy soil; keeping the mice hidden from their owl predators. However, volcanic eruptions have since spewed-out wide trails of black lava that weaves right through the middle of pocket mouse territory. Explain which variety of rock pocket of mice would flourish (do well) in this new volcanic landscape.

Hawaiian Crickets

Male crickets chirp to attract females. However, the chirps also attract a fly that deposits maggots onto the cricket's back. The maggots burrow into the cricket, eat him alive, and crawl out a week later. In the span of just a few years, about twenty generations of crickets, male crickets on Kauai have evolved from boisterous (noisy) to silent. A mutation produced a population of males unable to call for mates. The mute males have similar wings to females, which lack the noise producing structure. Explain why the majority of crickets in Hawaii are unable to chirp.

Rabbits

There are two types of rabbits in America's northeast: those that eat only grass and those that eat only berries and flowers. Significant drought occurs for a two-year time span, and the plants have difficulty producing any flowers or berries. Producing flowers and berries are necessary for a plant to reproduce but not for it to survive. Plants during this period of drought only try and keep themselves green. Rabbits have offspring all year long but many are eaten by foxes or hawks. Due to the drought, many more rabbits have starved to death. Explain how the rabbit population has changed and will continue to change the next few years.

Ostriches

The ostrich is the largest living species of bird and it is native to Africa. Although it is flightless, it has the ability to run at very high speeds. Some ostriches can commonly run between 35-45 miles per hour, but many ostriches can reach speeds between 46-50 miles per hour. Jackals love to eat ostrich, and they can reach speeds of up to 35-40 miles per hour. A flock of ostrich will lay approximately 20 eggs, but many rodents break into the eggs and eat the fetus before they hatch. Explain which variation has an advantage in producing more eggs in hopes that one or more will survive to adulthood.

Stickleback Fish

Sticklebacks are small fish that live in oceans, streams, and lakes across the northern hemisphere. Typically, armored sticklebacks thrive in the ocean and unarmored sticklebacks thrive in freshwater; however, both varieties can be found in some freshwater streams. Low-armored fish grow faster, making them too big for predators at an early age. They are also able to reproduce at a younger age. Fully-armored sticklebacks require more energy to survive and therefore grow and mature at a slower pace. Explain which variety would have greater success in the freshwater stream.

Galapagos Finches

Charles Darwin observed many varieties of finches on the Galapagos Islands. He was amazed by the diversity of the finches living on the island. Each finch had a different type of beak adapted to eat a specific type of food. Environments often change; a drought hit one of the islands and seeds became scarce. As a result, most finches were not able to reproduce and the offspring of those that were able to reproduce often died. There were two main types of beaks found in finches on the islands. Large and small beak finches quickly ate all of the small soft seeds. Soon only large tough seeds were left for the finches to eat. Finches with smaller beaks were unable to crack the tough outer layer of seeds. Finches with the largest, strongest beaks were able to eat the large, tough seeds.

Explain how the drought affected the evolution of beak size over the next several generations.

Teaching Strategies

This unit is designed to incorporate the school's literacy focus and create a scientific understanding of the theory of natural selection and the role disasters might play. The literacy initiative requires students to read, write, speak, and listen at a proficient level in accordance with PSAT and SAT scores. Tenth grade biology students participating in this unit will be assessed on their content knowledge by a district-mandated unit assessment and their literacy skills by the PSAT. These results will then be used to measure the effectiveness of teachers. To comply with the school-wide implementation to improve literacy, the unit contains reading, writing, listening, and speaking opportunities for students. The unit scaffolds from an introductory activity where students participate in simulations and organize information on why populations change over time, how long has change in species been taking place, to evidence supporting the changes in populations. By the end of the unit, students are applying their knowledge of natural selection to real-world scenarios where natural or man-made disasters impact an ecosystem.

Jig sawing information chunks the information to alleviate the amount of new content students are exposed to at one time. This is important for the introductory activity where students are experiencing multiple new vocabulary terms and new content. Chunking the content and asking students to summarize small portions of information allows for deeper understanding when building upon the knowledge. Providing students time to gallery walk, or walk around the classroom observing and collecting information, creates time for content absorption. This unit divides the gathering and sharing of information into separate days to allow for ease into the unit. In the gallery walk, students are collecting the answers to questions they did not need to focus on.

Labs and simulations are an important piece of this unit because in order to understand the concepts of natural selection, experiencing it is the easiest way to comprehension. Through tactile lessons, students have memories they are able to reflect back on throughout the remainder of the unit. It is impossible to bring real scenarios into the classroom, but creating fictional scenarios allows students to role play natural selection. Labs are a succinct way to incorporate, observation, reading, writing, peer collaboration, and critical thinking into a short time period. It also creates an avenue for class discussion when reviewing and analyzing results and conclusions.

Using visual representation as a model to construct an explanation provides students the opportunity to express themselves in a different way. Traditionally, the fourth activity would have been conducted having students write their responses to the scenarios and the teacher grading them; giving little time for reflection and peer collaboration. This unit enables students to experience multiple real-world scenarios with their peers, practice organizing information using words, followed by a visual demonstration of understanding. Students are able to share their knowledge by explaining their drawings to their classmates.

The Next Generation Science Standards ask students to construct and communicate explanations based upon evidence through writing and modeling. Written responses are collected as informal assessments for the instructor to gauge student progress, this knowledge will eventually be incorporated into the culminating drawing assignment. The final model that students create and share with the class are graded on a rubric that includes both the visual and the explanation.

Classroom Activities

Web Quest Jigsaw

The introduction into natural selection is divided into three mini sections. All portions of the assignment utilize different sections on the Learn.Genetics website; the link can be found under Student Resources. Part one of the jigsaw asks students to play a simulation and two videos and complete a graphic organizer for students to take note on the key points of natural selection. This introduces students into the importance and process of variation within a population. A class discussion surrounding the simulation and videos is useful in explaining terminology and addressing student questions and misconceptions.

The second piece of the jigsaw is a further jigsaw that the student's piece together based on the explorations of change over time. The teacher should prepare questions for the first three simulations and readings. All questions are cut into strips and posted on the board under the title of the simulation. Students are to choose three questions from the board, one from each topic, to answer and re-post the question with the answer on the board. This requires all students to experience the three items, yet only focus on answering three questions in total. Utilizing all students within the class, each question is answered at least one time per class. Between class days, the teacher sorts through the responses and chooses one answer per question. Student responses are posted around the classroom for a gallery walk to copy down answers. This is considered student notes for the unit introducing students to all vocabulary terms and concepts on natural selection and evidence for evolution. These notes will be used in future units as part of evidence for evolution and why evolution matters now.

The final piece to the jigsaw involves the Evolution in Action case studies. These provide the students an opportunity to read about real examples, some that they may have observed such as artificial selection and the evolution of corn. The goal for this section is exposure. Of the six scenarios, students are only to choose three topics of their choice and write a four-sentence summary and one sentence about what the student found most fascinating. These summaries are added to the gallery walk for students to explore all six topics briefly through the summaries without having to read the lengthy articles.

Peppered Moths Simulation

Students complete a Gizmo assignment walking them through the change in frequency of peppered moths in Manchester, England. An alternative website that I have also used with my students is located under Student Resources since Explore Learning requires a purchasing license. Students explore scenarios where the environment changes and therefore the gene frequency of light moths to dark moths changes accordingly.

Bird Beak Lab

The Bird Beak Lab is completed in groups of three students; each student embodies a fictional bird with a unique beak: spoon, chopsticks, clothespin. The birds visit four different environments where there is a single source of food with the intention of gathering as many food items as possible in fifteen seconds. These environments include worms (toothpicks), seeds (beans), bingo chips (bugs), and fruit (noodles). Students record their data in a data table and add their results to the class' results posted on the board. The class average for each food item consumed is calculated and recorded onto individual data sheets. Using given information for how many calories are in each food item, students calculate the amount of energy accrued by "eating" each food and comparing it to the number of calories required for survival and number of calories required for reproduction. Students then determine the potential success in each environment for the various bird species.

The analysis component asks students to apply their knowledge of natural selection to the lab. Student responses are written using the CER format – claim, evidence, reasoning – in accordance with the Next Generation Science Standards. Students ideally observe each bird beak is successful in different environments. Individuals are able to explain how and why multiple varieties of birds are able to live in an environment with all four food options. If a mutation arose within the bird population with a beak shaped like a fork or a straw, how would it survive in comparison to the other birds. Students predict the success of the beak based on basic survival and ability to reproduce. To broaden the impact of nature, a disease hits the "worm" population; so, students are faced with determining how this would impact each of the bird populations. At this point in time, although not directly taught, students are being exposed to the idea of natural selection.

Case Studies Gallery Walk

This activity is designed as stations with a final gallery walk piece. Ten examples of natural selection are arranged around the room with a frayer diagram at each station. Examples range from Galapagos finches, Galapagos tortoises, Ugandan elephants, rabbit color, rock pocket mice, stickleback fish, Hawaiian crickets, Prior to breaking students into groups, the acronym "Very Carefully Explain your Answer" is reviewed as a class to explain how natural selection scenarios are analyzed: "V" in very stands for variation, "C" in carefully represents competition or the struggle for survival, "E" in explain suggests the environment, and "A" in Answer stands for advantage or differential for survival and reproduction. These components are the four quadrants in the frayer diagram posted at each station.

Students are divided into groups of three to four and move to one of the scenarios. Each group reads their unique scenario and completes the "variation" box on the organizer. After approximately two minutes, groups rotate and read a new scenario and the variations written down by the previous group. They then complete the "competition" box. Groups continue to rotate two more times, each time recording the information for a new quadrant on the frayer. Creating this activity into stations, allows students to experience multiple case studies. Once the organizer has been complete, groups rotate one final time, read the scenario and the organizer completed by peers and then visually represents natural selection in action. Students were not permitted to write on their posters beyond simple labels. Finished posters are hung around the classroom and each group presents their drawing to the class.

Student Resources

Learn.Genetics. Variation, Selection, Time. Retrieved from https://learn.genetics.utah.edu/content/selection/

This website is used for the web quest jigsaw activity. The first three links are used for part one which includes a graphic organizer. The Change Over Time section is used for part two, jigsaw questions, and Evolution in Action is used for part three, summarizing case studies.

Pepper Moths. Retrieved from http://peppermoths.weebly.com/

This web site is one option to use when conducting the peppered moths' simulation. If your school invests in www.explorelearning.com; their website also has a peppered moth simulation that includes graphs and charts.

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Appendix 1

Next Generation Science Standards

HS-LS4-3. Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.

This standard is addressed throughout the videos and case studies. Students explain reasoning behind advantageous traits in the Bird Beak Lab extension questions and in the Case Study activity.

HS-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

Students address this standard in the Bird Beak Lab and case study poster.

HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

This standard is addressed during the Bird Beak lab and its extension questions.

Notes

[1] (Tort 2001, 34)
[2] (Tort 2001, 29)
[3] (Tort 2001, 33)

[4] (Tort 2001, 42-43)
[5] (Tort 2001, 49)
[6] (Tort 2001, 50)
[7] (Tort 2001, 51)
[8] (Tort 2001, 51)
[9] (Tort 2001, 58-59)
[10] (Tort 2001, 63)
[11] (Allendorf and Hard 2009)
[12] (Allendorf and Hard 2009)
[13] (Allendorf and Hard 2009)
[14] (Siepielski, et al. 2017)
[15] (Siepielski, et al. 2017)
[16] (Siepielski, et al. 2017)
[17] (Siepielski, et al. 2017)
[18] (Botanic Gardens Conservation International n.d.)
[19] (Botanic Gardens Conservation International n.d.)
[20] (Holdrege 1999)
[21] (Holdrege 1999)
[22] (Holdrege 1999)
[23] (Holdrege 1999)
[24] (Tort 2001, 50)
[25] (Tort 2001, 51)
[26] (Grant and Grant 2014, 7)
[27] (Grant and Grant 2014, 7)
[28] (Grant and Grant 2014, 21)
[29] (Grant and Grant 2014, 12)
[30] (Grant and Grant 2014, 14)