Yale National Initiative
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Curriculum Units by Fellows of the National Initiative
2016 Volume VI: Making Sense of Evolution

Silent Witnesses: Hexapod Helpers in Crime Scene Investigation

Curriculum Unit 16.06.01, published September 2016
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Introduction

Prime time television shows glamorize crime scene investigation, hence increasing the popularity of high school forensic science course offerings. Being socially popularized, however, does not equate to generating academic strength in a subject. In this course, students must combine skills across each of the core sciences, as well as learn to read critically, calculate accurately, and argue cogently. My role as a teacher is to entice student engagement and to provide them with meaningful experiences that enhance learning.

Incorporating a unit on forensic entomology enhances a course that often favors the study of physical sciences related to violent crime, such as explosions, gunshots, and vehicular collisions. The topic invites students to not only examine their natural world, but rather to engage themselves with it. In this unit, a student could become the forensic entomologist who calculates the number of days that a body has been exposed to the environment based on the blow fly life cycle. Another student could become the international trade specialist who defends or prosecutes an illegal insect collector. Insects work dutifully as silent witnesses, and forensic entomologists must provide a voice for them in the court of law. The ability to practice applied knowledge of these species – a study originating from understanding mechanisms of evolution – is thus essential to these specialists.

School Environment

Approximately 1200 students attend Oak Grove High School, located in south San José, California. It is one of eleven traditional high schools in the East Side Union High School District, which also includes seven alternative education high schools and an Adult Education Program (AEP). Students who attend Oak Grove High School represent diverse socio-economic, racial and ethnic, and social groups. Approximately 53% of students at Oak Grove High School qualify for California’s Free and Reduced Lunch status, based on income eligibility. According to our registrar’s demographic records, the three most represented racial groups are Hispanic, Asian, and White. Among these racial groups, the most common ethnic groups are Mexican and Vietnamese.

Students in my forensics class are reflective of the general ethnic population of the school and they come from a variety of academic achievement levels. Although Forensics is a rigorous course for which students should have completed both biology and chemistry with passing grades, several of my students have struggled in both subjects. Despite many of my students not having the expected background for a demanding course, I find that teaching Forensics serves a unique opportunity to repair the damaged egos from past academic failures. Calculating time of death is more interesting to many students than solving linear algebra problems. Explaining the progression of insects that decompose corpses can be more exciting than reciting definitions. Composing an evidence report establishes a mode of documentation essential to real-world writing, rather than for the sake of practice. Forensics provides a scaffold by which I find the intersections of chemistry, physics, and biology in a thoroughly integrated context that incorporates math, oral expression, literacy, writing, creativity, and critical thinking. The curricular unit proposed in this text focuses on learning about insects within the context of forensics for students in grades 10-12, although adaptable to other levels.

Rationale

Oak Grove High School offers forensics as a college-preparatory laboratory science course, typically for eleventh and twelfth graders. My students become part of the "behind-the-scenes" science of popular shows such as *CSI* and *Criminal Minds*. Besides television series, the increasing violent crime rate of San José and newer variations of cyber-crimes make forensics directly applicable to the lives and communities of our students. Forensics additionally offers previews of several careers that may stem from each of our curricular units: crime scene reconstruction, investigation, crime scene photography, medical examination, pathology, entomology, medico-legal perspectives, cryptology, and more. The application of current, local news invites students to engage and advocate for authentic investigation for the science of the justice system.

The goal of my unit is to teach my students about natural variation in insect populations by using various teaching strategies that extend student skills. The current problem with some of the preferred lessons about evolution, although rich in content and strong in reliability, is that they use whales, finches, peppered moths, and microbes. With these examples, students often only see images, occasionally manipulate models, or observe samples through a microscope while using pre-published field and laboratory reports. While this is educationally sound and exciting to those who are already interested, these creatures still remain intangible to students regardless of how well they exemplify the effects of evolution in action. Insects are easily examined in their natural environments and students can observe variation within the population on a macroscopic level. Insects also have this special role in forensics because they have abundant species varieties, which perform specific activities and are found in different geographic areas.

A secondary goal of this unit is to comfort those who argue that teaching evolution is controversial because some teachers might face resistance from students, families, and communities. Ample evidence exists to prove the mechanisms of evolution and the observed occurrence of the process itself. Presenting evolution as an idea at odds with religion erroneously supports that they are mutually exclusive, whereas that is not the case. They populate separate realms of thinking, as articulated by the late evolutionary biologist Stephen Jay Gould in his introduction to the essay *Nonoverlapping Magisteria*, "Science and religion are not in conflict, for their teachings occupy distinctly different domains."[1]

Lastly, learning and teaching evolution must be directly useful to career options. Insects conveniently exist everywhere relevant to students. By fostering an appreciation for insects, this unit opens avenues for career exploration even beyond the sciences. Alternative career paths besides forensic entomology include preparing students for a future study of legal aspects of the insect trade, art/photography using insects, and public policy about the control of insect populations that threaten agriculture or that vector transmit viruses and other pathogens.

By the end of the unit, students will be able to categorize insects by taxonomic order and articulate that the importance of insects in forensics is due to their speciosity – the quality of having an abundance of species. The ability to complete these tasks depends on learning about evolutionary processes by meeting objectives derived from the Next Generation Science Standards, as will be described in the last section of this curricular unit.

Background

Insects have played vital roles in providing evidence in legal cases.[2] Entomologists use standard insects with well-documented life cycles in relation to the decomposition process. If only one type of insect existed, then entomologists would be unable to use characteristic behaviors to calculate the post-mortem interval (time of death). As such, insect speciosity is essential to crime scene investigations. For this, a general understanding of the factors that have led to multitudes of species is beneficial. This content overview presents four sub-sections: evolutionary biology, insect diversity, introductory classification, and the roles of insects in criminal investigations.

Evolutionary Biology

The primary emphasis of evolutionary biology is to examine the processes that contribute to the diversity of species from a common origin through descent. Even in the early history of insects, diverse species existed, filling ecological niches from areas heavy in vegetation to watersheds[3] . Each of these insects is generally suited to its environment, with features that increase the likelihood for survival. These features are known as adaptations. Discourse on specific details of adaptation is widely available, and many classic curricular units related to those topics exist, hence will not be addressed herein.

Besides adaptations that sometimes can be used as characteristic features of an organism, all organisms including insects express at least minimal degrees of variation, spanning across qualitative differences such as color range and color patterns. Quantitative differences may include overall size, body mass, and resistance to stimuli. It is well-established that individuals within a population can vary. Whether it was in Charles Darwin's original collections during his voyages as a naturalist with Captain FitzRoy on the HMS Beagle or in the color patterns of urban insects, visually observable differences exist. This understanding that all organisms exhibit some variation is among the four tenets of natural selection as popularized by Darwin. Even the variations in features invisible to the naked eye, such as human blood type, provide examples of natural variation. Being observed and documented, natural variation was accepted even before the notion and discovery of DNA and genes, although these minor differences originate on a genetic level. Each individual has slight differences in the genetic code (genotype). These slight differences may be expressed in the physical characteristics (phenotype) of an organism, such as wing length or keenness of eyesight. As part of the genetic code, these minor differences are heritable in a population, meaning that it can be passed down from parents to offspring.

Physical traits that confer a survival, and hence reproductive, advantage allow the genotypes that coded those traits to be passed down to subsequent generations. The ability to survive and reproduce (described using the biological term *fitness*) differs for each member of that species. As a result, the survival and reproduction rates become non-random, and some traits are perpetuated in the population. Through this selection process across very many generations, some descended forms will no longer resemble those of the original ancestral genotype or species due to various selection pressures. Natural selection describes the process for changes within a population, ultimately being one of the mechanisms that can lead to speciation.

Species themselves are defined as distinct once they are no longer able to interbreed to produce fertile offspring. The process of speciation requires selective pressures that create a genetic isolation that has resulted from range expansion and physical boundaries or limitations[4] . Whether this occurs through natural selection, sexual selection, artificial selection, genetic drift, bottleneck effects, or other evolutionary forces, some groups of organisms exhibit more speciosity than others.

Speciosity, sometimes referred to as species richness, describes the propensity for some groups of organisms to be more speciose (having more species represented in the group) than others. Plants, for instance, can be subdivided into cone-bearing plants and flowering plants, of which there are many more varieties of the latter. The factor that is attributed to flowering plants being more speciose is the flower itself, as a structure that can easily change through natural selection to match its environment and ultimately lead to new species formation. In animals, the arthropod limb is similarly considered easily molded by selection, thus contributing to speciosity in insects and other arthropods.[5]

Evolutionary biology includes a distinction between proximate and ultimate variables. As indicated by the term, proximate variables address actions or features that involve an organism's immediate lifetime, such as reproductive rate. Ultimate variables delve into the evolutionary history of an organism and hence providing reasons that support the proximate variables. The difference between proximate and ultimate variables is thus marked by the relative time that is being considered. Questions derived from proximate variables regarding insects would be: How do insects follow scents? Or: What types of insects are attracted to corpses? An ultimate question would be: Why are there so many different types of insects?

Insect Speciosity

The fossil record indicates that insects preceded humans on this planet.[6] Hexapods that included early proto-insects are in the fossil record as early as 411 – 407 million years ago, and likely descendants of these non-true insects are silverfish. Despite representing over half of the species that have been catalogued, explaining the richness of insect diversity posed problems. Peter Mayhew tabulates eighteen contributing hypotheses to explain why are there so many insects, of which four will be described in this background information. Ultimate factors pertinent to the morphology and ecology of hexapods fuel the proximate factors: clade age, high speciation rate, low extinction rate, and carrying capacity. Together, these generate the pattern of insect speciosity.[7]

Insects are members of a group of organisms known as arthropods, which includes commonly recognized animals such as spiders, centipedes, crustaceans, and insects. The term *arthropod* derives from Greek origins meaning "jointed feet". Each of its sub-categories is distinct. Spiders, for instance, have eight legs and a different body scheme from insects. Crustaceans not only include crabs and shrimp, but also some land creatures such as the pill bug, which all also differ from insects in various ways. Each of the aforementioned animals has different appendages with specialized features, whether in the form of legs, pedipalps, feelers, or wings. Research suggests that through diverse adaptive radiations, appendages are easily modifiable into a variety of forms.[8]

Insects of related categories tend to have similar shapes and structures on their bodies; however, some of these features are noticeable only during embryonic development. The labrum, for instance, is a structure associated with an embryonic fusion process that may have actually been remnants of an appendage.[9] Although that particular piece no longer exists as an appendage in most insects, there is still residual evidence for it.

In general, the small size of insects increases their ability to inhabit myriad fine-grained (small-sized) niches. Speciation rates can be driven by the opportunities to fill niches on the macro-evolutionary level.[10] Anecdotally, a colleague who breeds Madagascar hissing roaches (*Gromphadorhina portentosa*) once noted that he found young insects everywhere from his kitchen drawers to his bedroom, even though he housed his adult breeder beetles in terrariums with lids. In this case, if somehow these roaches became completely separated from others for sufficient generations, the isolated population could perhaps undergo its own selection pressures that ultimately give rise to new adaptations. This scenario is plausible because the environment provides extensive habitats and ecological niches relative to the body size of most insects. Conversely for other arthropods such as coconut crabs and giant isopods, members of those groups exceed several centimeters in size, and neither crustaceans nor isopods are nearly as speciose as insects.

Besides small body size, the relatively short generation cycles of many insects increase opportunities to recover from disturbances such as environmental changes.[11] When genes are shuffled during mating this creates variation; hence, species that have rapid generations can be favored in rapidly changing environments because abundant variants are available for the evolutionary process of natural selection to keep pace with changing habitats. However, survival of many offspring in each generation might consequently drive organisms to undergo dispersal to reduce local competition for resources. Slightly different from the idea of dispersal, range expansion is a component of speciation because it increases the likelihood that populations will become sufficiently isolated to prevent gene flow and interbreeding.

Taxonomy

With so many documented insect species, specialists must be able to recognize their features, ecology, and behavior. Whether seeking insects to perform decomposition functions or tracing evidence of illegal poaching and distribution, the geographic ranges and species diversity thus become cornerstones of forensic entomology.

Taxonomy refers to the classification of organisms. Carl Linnaeus developed what is now known as the Linnean system. Although genetically “truer” phylogenetic relationship systems now exist[12] , as well as the higher classification of Domain, only the conventions of the traditional Linnean system will be used for this curricular unit. In the Linnean system, organisms are sorted into the categories Kingdom, Phylum, Class, Order, Family, Genus, and Species, in which each descending group is a smaller subset of the previous. For instance, a Kingdom is a group of closely related Phyla (the plural form of Phylum). A Phylum is a group of closely related classes, and so on. Following that, Class will tend to be what a layperson uses in common reference, as in the class Insecta, simply as insects. A Linnean order subdivides Classes into the household names that a person may recognize, such as “beetles” for *Coleoptera* or “dragonflies” for *Odonata*. Those who recognize specific beetles, such as a ladybug or a firefly (for which, incidentally, ladybugs are not true bugs and a firefly is not a fly), are using Family, Genus, or Species names. Species refers to the most closely related organisms that can still interbreed to produce fertile offspring. Categorical charts that list each of the insect orders and representative members are easily available from textbooks and online resources, and will not be listed within this overview since the study of any particular insect should vary by location.

Taxonomical knowledge within the context of entomology is also important since not all species are located in all parts of the world. Knowing similarities enables comparisons to be made using regional species for assessment purposes. For instance, the *Calliphoridae* family of insects (the blowflies) are used for determining time of death. In Köln, Germany, the blowfly species *Lucilia ampullaceal* is well-documented, whereas in California (United States) *Lucilia sericata* is standard. Each of these species is found in particular climate conditions and function analogously to a calibrated piece of equipment when its life cycle is measured in conjunction with weather data.

Forensic Entomology

Post Mortem Interval

Pairing the notion of insects and crime conjures the image of maggots (fly larvae) wriggling in a corpse. This image is not entirely untrue, but it neglects the eventual presence of beetles and moths, where together, these three orders provide key evidence for determining the post-mortem interval. The decaying process emits different chemicals at specific points in time, hence has time-markers for the attraction of certain insect clientele[13] . The combined information of the insects present provides clues regarding time of death (or child neglect, etc.) and discovery by officials.

The green bottle fly (*Lucilia sericata*), a common blowfly, provides a well-documented and consistent life cycle of value to forensic entomologists. Blowflies (*Calliphoridae* family) are fairly ubiquitous[14] . When used in conjunction with daily weather data, the life cycle of this species enables entomologists to calculate a reasonably precise date on which a corpse was first exposed to the environment. This initial exposure is known as the minimum post mortem interval and contributes to clues that piece together an investigation. The life cycle spans approximately three weeks; the presence of only eggs indicates an exposure of potentially only hours. The mass and feature development of the maggots correlates to the number of days during which the maggots have been able to feast upon the body. Moreover, disturbances to the body, such as its movement from a different location, would consequently be reflected in disruptions to the blowflies’ development.

Fly evidence can also be used to exclude scenarios of some crime scenes that involve blood spatter evidence that was initially flagged as violent crime[15] . Blowflies consume blood but they also regurgitate it as part of their feeding habit. This behavior can produce patterns that appear similar to high-velocity blood spatter, characterized by small circular droplets, typically less than 1 mm in diameter. If these spatters are present, a cursory crime scene investigation may suggest there was slinging around of blood or a possible gunshot wound. If the bloodstain pattern is ultimately attributable to blowflies, then it could negate the latter possibilities. The minute differentiation of the blood spatter would be determined by analysis of whether most blood spatter tails point in one direction or whether the tails point toward multiple directions. Since fly meal timing can be estimated or calculated, the presence of regurgitated blood provides additional clues regarding the time of death.

Beetles, scientifically known as the order *Coleoptera*, generally arrive at a corpse after decomposition has progressed.[16] Unlike flies, beetles have a mandible that has the ability to cut flesh that has softened sufficiently. Additionally, some beetles may be attracted by the presence of fly maggots upon which they feed. The last beetles to arrive, if regionally present, will be those of the *Dermistid* family. *Dermestid* beetles consume dried skin and animal hide, and some species within this family have enzymes that break down keratin, the key component of hair and fingernails. The range of characteristics from mandible shape to enzymes confers survival advantages to beetles since they consequently do not compete for the same resources.

Moths and butterflies, *Lepidoptera*, are associated with advanced stages of decay.[17] Moths and butterflies are differentiated by foraging habits and body structures. Nocturnal foraging is more common for moths, whereas butterflies tend to be more active in the day. Moths have feathery antennae, and butterflies have club-ended antennae. Wing frenulums, a small connective tissue between the top and bottom wing, are more characteristic of moths rather than butterflies. Naturally, exceptions to each trend listed above exist for some species within each family. In the larval stages, several *Lepidoptera* consume mammalian hair or the mites associated with the hair. Eggs are often laid on exposed bone, especially when near foliage.

Poaching

Crime scenes do not necessarily involve violent crime and homicide and it is important to emphasize the range of crimes that actually exist. The term poaching often conjures images of large, charismatic animals such as lions, tigers, and bears (oh my), but insects are often captured and killed illegally. Common targets are butterflies and beetles with lustrous wing coverings. The Lacey Act[18] bans "interstate and international transport of endangered or protected species that have been illegally captured", but enforcement is not strict for insects. Full enforcement raises the concern that even innocuous collectors, museums, and researchers could be prosecuted if their specimens were collected illegally. Entomologically, it is important to be able to identify various species, sometimes a daunting task because some males and females of the same species are vastly different in size and color.

Collectors of rare insects may jeopardize the success of wild populations. Although the typical large population sizes of insects cause a tendency for them to be less threatened by extinction relative to quadrupeds, ecological concern should still be exercised.[19]

Strategies

Students participate in my Forensics course as though they are newly recruited investigators under my employment. All students are expected to be functional members of the class, and I use an invented wage and currency system ("Forensic Funds"), as an extra incentive. Forensic Funds can be earned by performing: extra tasks (extra lab set up, lab clean up, general housekeeping around the classroom); exceptional depth of thought; maintenance of difficult team behaviors or problems; and extending knowledge to others outside of the classroom. All students serve one of four roles in their assigned teams that are rotated every grading period (six weeks). These roles are Manager, Assistant, Technician, and Facilitator. The manager is expected to compile and examine each member's work for accuracy before submitting it to me. The assistant retrieves and returns materials as needed, typically for labs or worksheets. The technician follows lab guides to prepare stations and takes photos as needed. The facilitator monitors behavior of the team. When selecting the first facilitators at the start of the school year, I tend to assign this role to the most energetic student so that it begins with self-management.

My teaching strategies emphasize a recurring weekly structure in order to encourage students to plan responsibly. Students take guided two-column notes on Mondays (or any otherwise first day of the week, such as if a holiday falls on the Monday). Tuesdays and Wednesdays involve laboratory and field activities to encourage cooperation, skills building, and effective interaction among peers. Thursdays tend to be reading days, for which students complete "text rendering" assignments. Text rendering is a reading strategy that helps students quickly retrieve the main content by identifying all names/people, locations, and numbers within articles, described fully in Appendix 1. On Fridays, students take a short quiz (as formative assessment) that emphasizes vocabulary, events of pertinent legal cases, and key methods of analysis for the week's topics. After the quiz, students practice an oral review of providing an expert witness testimony as if they are testifying in court on Fridays. An agenda log is collected, reviewed, and submitted to me by each team's manager every two weeks. Students take a midterm and a cumulative final exam each semester.

Activities

The three-week unit begins with a basic overview of the role of forensic entomologists. This unit provides closure to the monthly insect hunts and documentation that students will have participated in for the duration of the school year, and therefore this unit should take place in the last grading period of the school year. Students have caught, photographed, sketched, and released insects in order to become familiar with the local insect species, trends year-round, and possible life cycles of some species. For teachers who do not intend to conduct monthly catches, a class period or two within the unit may be modified to accommodate field days, and thus timing this unit to be taught in the spring also increases the likelihood of catching live, adult insects.

Lesson Set 1: Introduction to Forensic Entomology

Students will take guided notes, watch a video clip, and render two articles about a case in which insects were an essential component in a legal case. The preferred video clip is Mike Rowe's *Dirtiest Jobs: Bug Detectives* (Season 7, Episode 8), however, many publically available alternatives would suffice[20] . Students use a "Quad Note" taking format, in which they systematically log key information, similar to Text Rendering. At the time of writing this curricular unit, the preferred article in which an insect species was used to identify a suspect is Lynn Kimsey's 2007 Los Angeles Times newspaper article, *The Case of the Red-Shanked Grasshopper*[21] *.* An article about insect poaching is the article *Butterfly Poaching* referenced from American University (Washington, D.C.).

Supporting activities in this first week involve reviewing the forensic definition of evidence and how it is assessed, learning the insects presented in the video and article, discussing the differences in life cycles between types of insects, and recognizing scientific names. Students will participate in the "Silent Witness" activity, in which they rank a small plastic bag of evidence items (either fictitious or adapted from simulation of a real case) in order of seeming importance, of which each evidence bag will include at least one desiccated insect sample. Students record their findings in their lab notebooks, and receive credit for completion rather than agreement with the teacher's opinion. The purpose of this ranking exercise is for students to have discussions with their small lab groups and practice articulating and defending ideas.

At the end of the week, the teacher should present options for a project related to the unit. The two basic options, described in the Project section of this unit, should be either to create a menu or order form for illegal collectors or to produce a field guide of local insects. Some students may opt to conduct a case study or produce a video documentary, and these are excellent options for highly motivated students, hence will not be described as part of this unit.

Lesson Set 2: Research and Documentation

Guided notes for the second week should introduce formal categories of insects, with special attention to the nomenclature using genus and species, and the taxonomic order. Students should examine several *Coleoptera* (beetles), *Hymenoptera* (ants/bees/wasps), *Odonata* (dragonflies), *Mantidae* (mantids), *Hemiptera* (cicada), *Blattodea* (roaches), and *Diptera* (flies and mosquitos). Using the insects that lab teams have caught, groups will be able to categorize insects by order, and then further divide them into as specific a taxonomy group as possible. Student teams should expect to catch and observe a minimum of thirty specimens, of which most will be released into the area of the campus from which they were caught. With discussion in lab groups, students next agree upon a range of variation for each of the species of insects that they can define as a team. For example, the number of spots on a ladybug indicates a species; however, minor variations among each of the ones that have the same number of spots should be determined, documented, and defined. In learning taxonomies, students will also compare images of international species that are similar but different to their local key. Although not especially important in forensics, ladybugs are fairly common across the United States, and students should know that the spots on ladybugs are indicative of different species, not age or sex of the insect. For more information regarding citizen science regarding ladybugs, students can access the Lost Ladybug Project website.[22]

In researching their catches, students will find that their collection represents the regional species. Students may observe anomalous specimens, such as if they were very similar to the expected local species yet exhibiting a feature that makes it stand out as very different. An example would be finding a flying cockroach rather than the typical crawling type. The students will need to decide whether these are invasive species or whether it is a member of another population that has crossed some geographic borders. I suggest preparing a regional list or a website that documents local species. Several of these may be available from local universities, such as at the San Jose State University (SJSU) Entomology Collection and Museum. Depending on timing and access, teachers may invite a local entomologist to share his or her collections with the class. In the past, I have invited Carlos Stephens, a representative of SJSU's Entomology Museum, and serendipitously, he is a graduate from my students' high school district.

Lesson Set 3: Expert Witnesses

The third week combines the tasks of the two former components. Students will practice a skill learned in the first semester regarding scale factor by calculating the actual size of an insect using comparison to a reference in the photograph, such as a standard United States coin. After this exercise, teachers should pose a question in which the *Elytra* beetles are bred so that their elytra (wing covers) can be harvested for use in ornamental jewelry. These captive-bred insects are contrasted against a similar practice that involves poaching and illegal import/export of endangered beetles with beautiful wing coverings. Students will keep this question in mind throughout the week.

The final component of the lesson set is for students to testify as expert witnesses in an excerpted form of mock trial keeping in mind the context of the *Elytra* beetles. An expert witness is a person who has a specialty in a particular field and as such can explain evidence findings. An expert witness in entomology should thus be able to provide background about the role of insects in general as well as specific to the case. The distinction should be clear that an expert witness is not simply a person who has seen many crimes, but rather he or she is a subject-area specialist who is able to testify to provide detailed analysis based on evidence submitted to him or her. Selected students respond to questions regarding their profession, justify their identification of given insect specimens, and defend the reliability of possible evidence as studied. In these simulations, students are assigned roles as expert witnesses. In preparation, students should select a university affiliation of their choice, state their degree title, and respond to questions. The sets of questions will range in depth of knowledge, from factual information to inferences, predictions, and rationalization.

Culminating Project Options

To complete the extended assignment supporting this unit, students have the option of either creating a menu or a field guide. The project options are fairly flexible, however, teachers may need to restrict choices or provide more guidance depending on their own students. The basic scoring guide for either task is the same in that students must include accurately drawn or photographed (not downloaded) images, taxonomies (order, genus, and species), and provision of additional facts.

The menu could range in creativity from a fictitious local insect restaurant to creating an “order form” for commonly poached insects with alternatives based on common local species. It should resemble an actual menu as though from a restaurant, including a title, accurate images, and scientific names. Prices, such as the fetching price for illegal trade or the price associated with prosecution, should also be included.

Making a field guide involves researching the species and their forensic uses, if any. The field guide will explain the usability of the insect species in a forensic case. For example, is there minimal variation within the regional population of insects? If so, then it could be highly useful to find a representative of the species that is very different since that would indicate it is likely from a different location. Blowflies are also highly useful to forensic entomologists; their life cycle is well-documented and can fairly reliably predict the day when a corpse was introduced to the environment. A species very common in the region would be less useful than one that does not live in the wild in the region.

Lesson Differentiation

Each component of the unit may be differentiated to accommodate various student needs. For instance, the minimum number of notes may be set higher or lower depending on student English proficiency. Teachers may choose articles based on news stories that are more local than the ones I use in my lessons. Allowing students to select articles may also increase their ability to select credible articles from reliable sources.

Once the project has been assigned, teachers may opt to provide work time for students during class in order to monitor progress or to schedule time to check in with students. This may be particularly helpful if the students will complete the projects in small groups or if students generally do not have computer and internet access outside of school.

An option to differentiate the Expert Witness activity, especially for students who have educational accommodations related to oral presentations, would be for students to compose a written evidence report instead of orally testifying. An evidence report formally summarizes the findings from analysis of a specific sample retrieved from a crime scene, typically in comparison to reference samples. Writing evidence reports exercises analytical writing skills of students. The task also refines formal writing performance since information must be conveyed using neutral word choices that deliver information that may be used for legal assessment. For example, students are guided to avoid using terms such as “match” and “guilty”. Alternative terms to describe a “match” could be “consistent with the reference sample” or “the evidence sample cannot be excluded.” The purpose of composing an evidence report is to present objective information through which pieces must be combined during court discussion. True (real life) evidence reports may span several pages, but I assign a 200-word maximum to encourage succinct yet thorough analysis.

Supplemental Teacher Ancillaries

Text Rendering

This is a method to help students extract key information quickly, especially if the reading level of the article is above a student’s typical practice.

1. Copy the title of the article.
2. Who is the author of the article?
3. What is the source of the article? (E.g. Website, textbook, magazine, etc. and state it specifically)
4. When (what year) was this article published?
5. In a three-column table, copy all people (names, professions), places (locations, institutes, countries, etc.), and numbers with units (dates, years, quantities, etc.)
6. Copy the most important word in the article.
7. Copy the most important phrase in the article.
8. Copy the most important sentence in the article.
9. Explain why you chose those combinations as your “most importants”.
10. Draw a picture that demonstrates the meaning of the article.

Quad Notes

This is an adaptable and transferrable method of taking notes when watching a video. It reduces the need for a teacher to generate a guided question set for students each time a video is shown.

Fold a blank paper into quarters. Label each of the quadrants as follows: 1. Key Terms related to the unit; 2. Names, Numbers, Places (for the same style as in the Text Rendering); 3. Questions regarding the video content; and 4. Drawing. As the video is shown, student should populate each of the quadrants with at least 7 – 10 entries. This may be modified depending on student ability levels.

Appendix: Alignment to Educational Standards

The movement toward Next Generation Science Standards (NGSS) drives educators to find ways for students to demonstrate their knowledge rather than regurgitate facts. Likewise, Common Core goals encourage building strengths between skills and content. In the unit proposed, students apply each of the components of Common Core goals including citing evidence, evaluating hypotheses, and presenting claims. Students creatively and collaboratively work to draw conclusions, while faced with open-ended questions. This section lists the NGSS and Common Core standards addressed by this unit.

Objectives for this unit are for students to perform the following tasks: 1) assess similarities in anatomical structures of species, 2) gather (document) data relevant to observations, and 3) defend inferences using the evidence gathered from those observations. Each of these three supports the cross-cutting concepts guided by the NGSS.

Next Generation Science Standards

HS-LS4-1 Biological Evolution: Unity and Diversity

Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.

HS-LS4-4 Biological Evolution: Unity and Diversity

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

HS-LS4-5 Biological Evolution: Unity and Diversity

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.

Common Core State Standards (California)

College and Career Readiness Anchor Standards for Writing

8. Gather relevant information from multiple print and digital sources, assess the credibility and accuracy of each source, and integrate the information while avoiding plagiarism.

9. Draw evidence from literary and/or informational texts to support analysis, reflection, and research.

Production and Distribution of Writing

Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information

Speaking and Listening Standards

Present information, findings, and supporting evidence (e.g., reflective, historical investigation, response to literature presentations), conveying a clear and distinct perspective and a logical argument, such that listeners can follow the

line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks. Use appropriate eye contact, adequate volume, and clear pronunciation.

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20. “Bug Detectives.” Dirty Jobs. Discovery. Season 7, episode 8. Broadcasted on November 28, 2010.
21. Kimsey, Lynn. The Case of the Red-Shanked Grasshopper. Los Angeles Times, July 4, 2007.
22. Lost Ladybug Project. http://www.lostladybug.org/ Accessed on 27 June 2016.

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“Bug Detectives.” Dirty Jobs. Discovery. Season 7, episode 8. Broadcasted on November 28, 2010. This episode presents a lively overview of work as at the Forensic Entomology Research Center (FERC) at Purdue University, featuring examples of the behaviors of maggots at four stages of decomposition of pig cadavers.

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