A Place at the Table: GMOs and Sustainability

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> *"To the people whose labors go beyond ideas into the realm of "real materials"—to the dry-land ecologists, wherever they may be in whatever time the work, this effort at prediction is dedicated in humility and admiration."* [1]

Content Objectives | A Rationale for Teaching Sustainability

It is perhaps ironic, that the music playing in the background, as I sit down to write this introduction is from a screen adaptation of Frank Herbert's ecological novel, *Dune*, a book which chronicles the religious and political history of a fictional sentient planet with limited natural and economic resources. I remember sitting in the back of an empty classroom reading Herbert's dedication of the book with some astonishment, at the time not quite comprehending the fragility of a desert ecosystem. Some 33 years after I first picked up the book, I am still finding inspiration in the ideas presented by Herbert and questioning myself. Now as I stand at the front of the classroom, I am aware that we humans have not done nearly enough to preserve the planet. Water rights, pollution, climate change and species extinction stories appear on news feeds daily. As I watch our political houses clashing in the media, the parallels between science fiction and reality are deeply troubling.

At the moment, I am re-reading Walter K. Dodd's *Humanity's Footprint*, a grim recitation of devastating statistics, recounting the atrocities humans have inflicted on our planet, crimes of negligence and outright murder based on the erroneous assumption that human life is superior to other forms of life, that other forms of life by reason of their lack of complexity or organization are not vital to our own existence. For instance, the human population continues to grow at an exponential rate by more than 200,000 people each day,[2] in spite of the fact that there is a finite amount of area on the planet's surface where humans can live. Factors such as, hyper-expansion of the economy, increased energy consumption, overuse of natural resources such as water, and modern agricultural practices compound the effect the human species has on the environment.[3] Humans are walking a dangerous path on the Earth; balanced against our economic wants are the needs of millions of other species who share this planet with us. In our single minded determination to conquer the natural world and build nations, we may have destroyed the planet that gave rise to our species. Pollution, water and food shortages, global warming, mass extinction of thousands of species, and unpredictable weather patterns are just some of the consequences if human societies continue on the current self-destructive path.[4] We would be foolish to think that our demise lies in some far-off future. The reality is that we have already begun to see the effects of industrialism and unsustainable agricultural practices. If we want a better world for ourselves, our children and their descendants, we need to create positive and lasting change and we need to start now. We have fouled our home like a methamphetamine addict who is only interested in the next fix; only an arrogant, self-absorbed and ignorant organism would destroy its own habitat. [5] Humans seem to be deeply addicted to consumption and acquisition,[6] a set of behaviors that has allowed the species to multiply and spread out across the planet. In order to continue to survive, we have to overcome ingrained behavior patterns. Clearly, our way of life as composer Phillip Glass might say, "calls out for another way of living." [7] One of the virtues of humans, if I may reference yet another Science Fiction classic[8] is hope. If humanity can mend its ways, we can change the path, change the possibilities.

My parent's generation believed in a sort of shallow ecology, thinking that science and technology could fix any problem created by human industry. But activists from diverse fields emerging in the 1960s and 1970s such as James Herbert, the Cousteau family, Rachel Carson and Jane Goodall reflect a concern about how humans affect non-human populations by changing the physical environment, acknowledging the rights of organisms of all levels of complexity to live, known today as Deep Ecology. The modern Deep Ecology and Green Religion movements that see science as evidence of the divine share a similarity to older aboriginal religious traditions. What the ancient and modern religions share is a reverence for the planet that sustains our lives, an understanding that all life is sacred and an acknowledgement of our place within natural cycles. It is this understanding that separates these religions from the apocalyptic vision of radical environmentalism. [9] The future envisioned by modern green religions, accepts that future human populations must have a significantly smaller impact on the planet in order to allow the biosphere to recover. Even mainstream religions have begun to echo the cry for stewardship of the resources of the Earth.[10] What then, can we do to mitigate the damage we have already done? We have to change how we do business, how and where we choose to live, where we find energy to heat and cool our homes, our transportation, even how we grow our food if the planet is to recover.

Human Behavior and Game Theory

> *"The window of opportunity to stave off catastrophic change is getting narrow, and we've already spent too much time talking."*[11]

Aquatic Ecologist Walter K. Dodd notes that there are four basic human behaviors that influence how we treat the environment: 1) the drive to reproduce, 2) the need to control our surroundings to improve survival and comfort, 3) the desire to flaunt resources and 4) the tendency to cooperate only with closely related individuals. [12] These are the behaviors we have to overcome in order to remain a viable species. As early as 1968, economist Graham Harvey noted these tendencies in his work *The Tragedy of the Commons*[13] that explored the ecological and economic exploitation that occurs when common public resources are not regulated. Dodd uses Game Theory, a way to study and predict the outcome of social or economic competition and cooperation,[14] to discuss dealing with the resistance to changing deep-rooted behavior, behavior that has to change in order for our species to survive. As governments are slow to react to climate change, Dodd, Bullock and others[15] promote a multidisciplinary approach[16] to dealing with this crisis, using grassroots organizations as well as taking action using ecological sciences, behavioral science, social sciences, economics, education and religion.[17] That is why it is so encouraging to see a number of disparate disciplines such as education, science and religion promoting the idea of sustainability. Education and social pressure will not be sufficient. Socio-environmental restoration will require a system of checks and incentives, peer pressure, cooperation, commitment, an information feedback system, and a voice in the process and choices[18] for the end consumer. There is hope that using all our knowledge and skills to address the problem using technology, social pressure, economic incentives that we can reverse our suicidal course. The question is not if climate change we have induced will affect the human species, but when and where we will begin to experience the effects personally. Unfortunately, that moment may be upon us.

Food production: The weak link

"We are in a race between political tipping points and natural tipping points."[19]

Lester Brown of the Earth Watch Policy group has been monitoring the effects of global climate change, watching what he calls an economic Ponzi scheme, as governments gamble with their natural resources, which will eventually lead to the collapse of nations. Deforestation, erosion, aquifer depletion and rising surface temperatures are some of the factors that have begun to affect the human food supply; what used to be an occasional disruption has become food scarcity in regions of the world. This, Lester claims is the weak link which will cause the collapse of our civilization.[20] There are environmental trends which humans could affect such as soil erosion, aquifer depletion, heat-waves, glacier melt, and rising sea levels that contribute to famine. And there are three resource trends that we could also change: the loss of cropland to non-farm uses, the diversion of irrigation water to cities, and the anticipated reduction in oil supplies. Finally there are consumption trends: population growth, the use of food crops as automotive fuels, and the increased consumption of grain-based animal proteins. Any one of these would cause a disruption in food supply, however, these trends combined, create an almost irreversible economic force that will tip our civilization, our species into decline.

These problems are overwhelming. Reversing environmental trends would require cooperation between nations. Halting the current resource trends would require cooperation between local and regional governments, but social, academic, and media pressure could be brought to bear. However, consumption trends are, in theory, entirely controllable. As one might expect, as the world population increases, there is an increased demand for grain. But in countries where population has stabilized, the population becomes more affluent and the more affluent a society, the more animal protein is consumed; animals which feed on the same grains as humans. This means there is an increased demand for grain. There are still regions of the world such as, Sub-Saharan Africa and the India, where the population is still increasing, but where growing conditions will not support sufficient agriculture production to feed the increased population.[21] Switching to biofuels for transportation has also increased the demand for grain. Clearly, sustainability is a complex problem that needs to be addressed from multiple fronts. Population control, eradicating poverty, reducing meat consumption and reversing biofuel policies are beyond the scope of conventional elementary school curriculum, but understanding the basics of plant propagation and genetics is not. Teaching students to see with wonder the reproduction of flowering plants is a good place to start in teaching about sustainability, making classroom lessons relevant to the real-world problem of hunger.

One of the reasons this topic was chosen was to support homeroom teachers in presenting the information in Genetics and Evolution, a new unit that is part of the Essential Standards for schools. The other reason is that I believe that understanding how our food supply is developed is critical knowledge that students need to have as consumers. What and how we choose to eat, what plants we cultivate, the agricultural methods we use, and how we transport our food are factors we humans can control. This will become more and more important as both the rate of climate change and world population increase. Humans need to skillfully use all the agricultural techniques we have developed to meet the needs of food and fuel production, from traditional plant breeding to genetically modified organisms (GMOs). Of these, GMOs are the least understood and the most controversial. This technological genie is out of the bottle, in use and already in the food supply chain, so as consumers, we need to become more educated about the process of creating GMOs. This new unit on Genetics and Evolution offers a place to begin building that background knowledge by introducing information on how DNA transmits genetic information.

Teaching Strategies

Poverty and hunger are familiar to my students. I work at a school that was established in an area which was once rural and poor. Years later, the school lies within the urban school district but it is still poor. Ninety-one percent of the students qualify for free meals. Over fifty percent of students live in households where no English is spoken, and so the students lag behind in reading, speaking and writing skills. However, most of the parents are passionate about their children's education. We are partnering with two churches and the local high school to convert part of the courtyard in the center of the school into a 4-season fruit and vegetable co-op garden for the families, fostering a social connection between the three groups, putting Game Theory to the test.

In an ideal world, I would have three hours a week to work with each class in the Library Media Center to develop a deep and meaningful research project. The reality is that I have 25 minutes a week and the part of the research project I cover depends heavily on what the homeroom teacher has done in the classroom. Marzano, Pickering and Pollock in their book, *Classroom Instruction that Works*, summarize the research on nine instructional strategies[22] that research has proved effective when combined with good classroom management and a well written teacher designed curriculum. In previous units I have worked on two, summarizing and non-linguistic representation. I will return to these, as students need practice on both, but I will also focus on using formal groups in cooperative learning and research, providing students with time to process information in small group through discussion and play.

The Big6 is a research method that is often used in elementary school libraries, but in order to support the work in the classroom, which changes topics from week to week, I also use the simplified Super3, KWL and Scientific Method when appropriate. In STEM/STEAM elementary schools, middle schools and high schools, interactive science notebooks are part of the research plan. Interactive notebooks are an excellent tool for students, not only to track their personal growth and understanding during the year, but as a creative way to teach observation, reflection and analysis. What begins as shared writing and review at the beginning of the year, with scaffolding becomes independent writing at the end of the term. The learning cycle begins with engagement or inquiry. It is during this step that the students pose questions, which are refined in class discussion. A key question is composed, which provides the focus for the second step, active research in small groups with concrete materials. Time for reflection is provided for the class to not only discuss the data and observations, but just as important, to create non-linguistic representations of their work. This is important--when students convert their understanding from concrete experience to a visual representation, it forces students to internalize the newly learned information.[23] The last step of a science investigation is application of new knowledge, which may or may not appear in their notebooks since it is usually a discussion and not graded; it acts to close the unit.

This writing intensive strategy is ill suited for the 25 minute once-a-week lesson, but there is a similar format that does provide inquiry opportunities, text-to-visual recomposing, and teaches non-fiction text cues—*Investigations*[24]. Readers are unknowingly familiar with this format which is successfully employed by publisher Dorling-Kindersley, featuring large glossy double spread “chapters” on brilliant glossy white paper. Investigations are brief one sheet research reports on a student-selected topic that allow the student to clarify, summarize or analyze the topic. Organically organized, each sub-topic features a sub-heading. Illustrations must be captioned and the writing must be concise in order to fit on a single page. Font size indicates whether the idea presented is a main idea or a supporting detail. Like a word-cloud, the larger the font, the more important the idea. Investigations begin with a research plan in which the student formulates key questions, brainstorms resources, narrows down the resource list to select three and draws up a data-gathering plan. After the student has completed the research, s/he will list on the planning sheet the key points to be communicated along with supporting details. A sketch of the investigation is submitted with examples of the visuals that will support the main ideas before the student begins working on the final product.

Visual literacy is a hot concept currently with the implementation of the Common Core, but we have long understood that information is processed and stored in two forms, linguistic and visual as evidenced by mankind's earliest symbols--pictographs, so that what once was old is suddenly new again. When students re-create the visual model to accompany their notes, they are actively processing and integrating the new information.[25] Both the interactive notebook and single page investigations encourage multi-intelligence learning, but because of the time constraints, I plan to use investigations which pairs writing with the use of images.

The heart of writing in science is to help us construct our understanding of new concepts, by generating and testing hypotheses, recording our observations, analyzing data and making inferences. This type of writing requires a period of reflection, so these activities occur in lesson sets occurring over a 9-12 week period. The first class introduces the background information, using the science textbook, video clips or interactive animations. It is during this class that word banks of new vocabulary will be created, the research method reviewed and questions are posed. The second class will feature one of the short activities below which integrates the new vocabulary and the use of graphic organizers, creation of data sets, diagrams or other form of note-taking. The third class will be a period of reflection, allowing students to discuss what they learned, clarify their notes and diagrams, write about the activity and pose new questions. The final project at the end of the unit is a student-lead investigation into a topic related to heredity and genetics.

Classroom Activities

Background for Activity 1| Mendelian genetics

In the past, we have been able to increase grain yields through conventional breeding, irrigation and fertilization. [26] However production yields seem to have plateaued. As a solution to land use, Brown suggests double-cropping to increase food production, no-till agriculture to preserve the topsoil as well as developing social/cultural practices that foster a commitment to farming, such as land ownership. But just as clearly, there needs to be the development of crops that are drought tolerant, cold-tolerant as well as varieties that produce in a shorter amount of time.[27]One of the proposed solutions to ending hunger is the propagation of Genetically Modified Organisms (GMO) crops to meet the needs of our ever increasing population. GMO refers to organisms that have been genetically modified to express proteins that promote desired traits such as drought-tolerance, pesticide resistance, herbicide resistance, improved nutrition and pathogen resistance. To better understand the issues and concerns that surround GMOs, one needs to understand more conventional plant breeding methods.

Traditional plant breeding is ancient, beginning at about 8500 BCE when humans began to deliberately save seeds to plant. This is plant breeding by selection. By 7000 BCE, rice, corn, barley and wheat were domesticated and many of the other food crops grown today were domesticated within 2000 years. So, genetic modification could be said to have started through seed selection. By the 1700s, farmers knew enough about plant reproduction that they could hand pollinate to produce crop varieties better suited to local conditions. This is considered simple plant crossing. Heredity, however, was still a mystery, until Gregor Mendel shared his research on inheritance.

What Gregor Mendel did was to observe seven discontinuous traits in peas.[28] By selecting traits that were either present or not present, he made the observation that because some traits skipped a generation, the potential for that trait had to have been carried but not displayed until a second generation cross. Mendel described these traits as "recessive". A more dominant trait may appear in the first generation, covering but not eliminating the recessive trait. What Mendel proposed was that each trait was an individually packaged "factor" pair. Traits required one factor for the trait from each parent, therefore each reproductive cell must carry only one of the factors, or what scientists now call "genes". Mendel went on to propose that the visible trait, what we now call phenotype, may not reflect its gene pair (genotype). Scientists and farmers have used Mendel's research to develop cultivars, varieties of the same crop with slightly different genetic makeups, sometimes going so far as to emasculate plants by removing the anthers so that only plants with the desired traits would be allowed to pollinate.

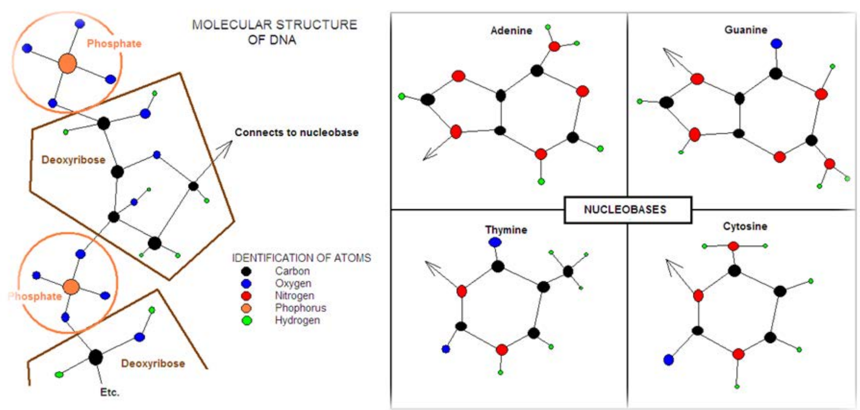
Activity1| Hasty Plants

Wisconsin Fast Plants is a kit that allows students to study dominant and recessive traits by germinating *brassica rapa* that show these traits in about 3 days. The kit contains parent seed stock and the F1 and F2 generations so that students can observe the inheritance of the recessive trait. The female parent is homozygous for a recessive allele that inhibits the production of anthocyanin, a purple pigment, while the male parent expresses the purple pigment which causes the color of his stem.

Students will be introduced to Gregor Mendel's work in their homerooms. A review will be provided through an article and video clips from Discovery education in the Media Center. In the second Media class, students will set up petri dishes with the P1, P2, F1 and F2 stock. The students will be asked to hypothesize the outcome and design their Punnett's Square. Students working in small groups will label petri dishes, count seeds into each and place them in water. Students will monitor their dishes in their classrooms during the week. The results will be counted, sketched and discussed in the next class.

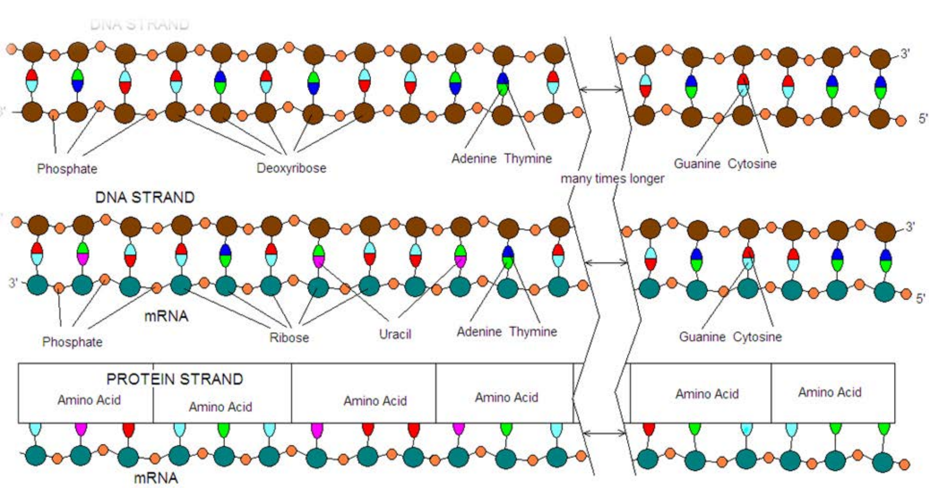
Background for Activity 2| DNA

Deoxyribonucleic acid (DNA), a large molecule that consists of six components arranged in three repeating units, is the blueprint that guides the construction of an organism.[29] The units consist of a phosphate, a sugar (deoxyribose) and one of four different nitrogen-containing bases: adenine, guanine, cytosine and thymine, as shown in the diagram below. These bases are nucleotides; in a DNA molecule, there can be thousands of these nucleotides held together by the bond between the deoxyribose and the phosphate. It is the sugar and phosphate bond which forms the backbone of the right-twist double helix DNA molecule, but the nucleotides on the interior are the ends that serve as the transcription model for protein creation.



[30]

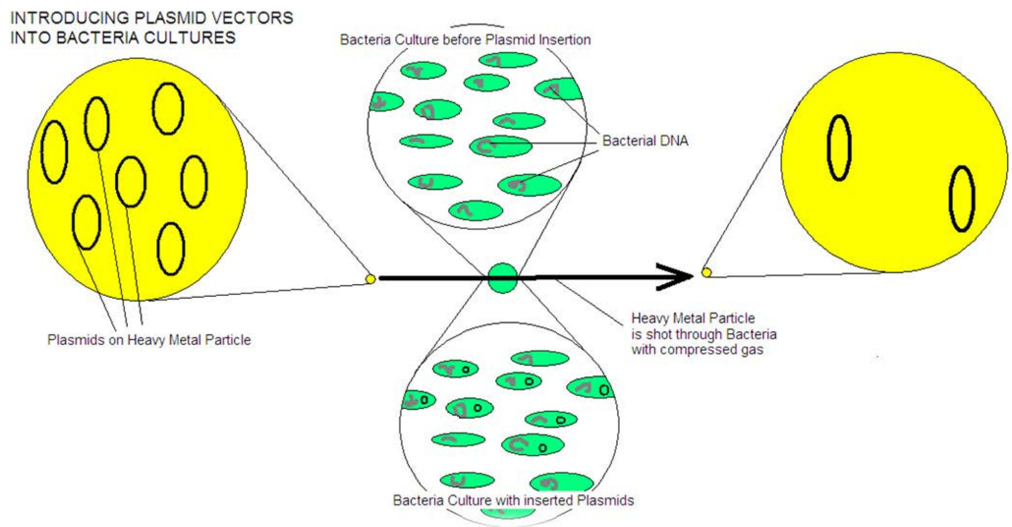
Along the interior, pairs of components are created by stable nucleotide bonds. Adenine pairs with thymine and guanine pairs with cytosine. A gene is a sequence length of these complimentary pairs that not only code for protein production, each gene has a beginning and end code that regulates (governs) the expression of that gene.



Because of the structure of DNA, it has directionality and each gene's transferable genetic information is "read" from the start code (codon), a deoxyribose that has an exposed phosphate group (5') to the stop codon (3') a deoxyribose that has a hydroxyl group, much like HTML coding or the old Morse code, with start and stop characters. To transcribe the DNA information into a protein, the an enzyme called an RNA polymerase (tRNA) builds a complementary 5'to 3' RNA strand beginning at the DNA's 5" end. This is the messenger RNA (mRNA) which then serves as a template for building a new protein. Ribosomes add new amino acids until the sequence has been replicated or translated as a protein.

It is this protein that when expressed shows up as a genotype. Once a gene has been isolated, the DNA segment to be replicated, primer segments of DNA, nucleotides, and DNA polymerase are placed in a test tube. The test tube is then subjected to heat which un-zips the DNA segment allowing the primers to attach. The primers act as stop/start codes for the polymerase which then build the complementary strand of DNA using the loose nucleotides in the test tube. Once the tube is allowed to cool, the DNA segment has been replicated, doubling the strands of DNA. [32] This heating and cooling cycle can be repeated over and over, until the reagents are consumed. Scientists can cut and splice these DNA segments into circles, called plasmids, using enzymes. This shape allows the segment to be introduced to bacteria, where it will be replicated each time the bacteria reproduces.

Inserting DNA into a host is still a mechanical process. One method is to coat gold or tungsten pellets with the DNA plasmids and shoot them into bacteria. This new genetic material is then introduced into a plant or animal cell using the host virus or bacteria to cross the cell membrane. This is because within a virus or bacteria, the genetic material is not enclosed within an additional membrane, as it is in higher level cells. Often placing DNA into the host bacteria's growth medium will be sufficient to introduce it, as the bacteria will absorb it along with the nutrients. For instance, when a common soil microbe, *Agrobacterium tumefaciens,* enters a plant through a cut or nick, it uses enzymes to cut and splice plant DNA replacing the plant's own DNA with genes that cause the plant to produce amino acids that benefit the bacteria as well as a growth hormone, which causes the plant cells to replicate uncontrollably.[33] Such bacteria are ideal for genetic engineers because they already have the mechanisms in place to genetically alter host plants.



Activity 2| Building a DNA Model

The students will use chenille stems and six colors of pony beads to create models of a DNA strand. This activity is directly drawn from a Resource Area for Teaching tip sheet. This is the simplest directions I could locate and features a video demonstrating how to create the form.[35] The six colors represent the phosphate group, the sugar, and the four nucleotide bases. Using a simple bead-weaving technique, students will create a DNA sequence. Beginning at the center of the stem, students will string beads representing the phosphate group, a sugar, a base pair, a sugar and a phosphate group. The bases must be paired correctly, adenine to thyme and guanine to cytosine. The stem is then bent so the phosphate is along the outer edge. Another set of sugars and base pairs are threaded on one end and the other end is threaded back through the set. The stem is snugged up until the second set of sugar and base pairs are aligned parallel to the first. Phosphate is added and the sequence is repeated until the end of the stem. The ends are fastened off, and the entire strand is twisted right until the double helix shape is obtained.

A higher level optional activity is a variation of one created by Joy Kilough.[36] This activity would be more appropriate for secondary school, but could be used by the teacher as a demonstration in a lower level classroom. The concept being taught is that the allele becomes visible through the expression of its phenotype. In Kilough's activity, student-teams create plasmid models using chenille pipe-cleaners loaded with pony beads that represent genes. Each team would need: 4 construction paper ovals to represent bacteria, 4 full length chenille pipe-cleaners loaded with pony beads closed to form a circle that represent the Prokaryotic chromosome in a bacteria, 3 half stems of identically patterned pony beads that represent plasmids to be inserted. Each team begins with 4 construction paper ovals that will represent bacteria, 4 full-length pipe cleaners, 3 half-stem pipe-cleaners and a selection of pony beads that include blue, purple, white and ultraviolet light sensitive (UV) beads. Reserve the blue, white, purple and UV beads for the plasmid models. The 4 longer pipe-cleaners are strung with sets of same color beads that represent "genes" and closed into a circle. Each of these proikaryotic "chromosomes" is placed in a construction paper oval representing bacteria. The teacher would then review how Restriction enzymes cut DNA before students create the plasmid models.[37] In this exercise, each group or set of single color beads represents a gene, blue represents the Lac Z' gene, purple represents the antibiotic resistant gene, and the "white" beads represent the allele being introduced. Each table will be supplied with pony beads, but there should not be sufficient purple, white or UV beads for everyone to complete the task. The students would then be asked to try to create plasmids using the following convention: the pattern must begin and end with a blue bead that represents the Lac Z' gene, the allele must contain a pair of purple beads that represent the antibiotic resistant gene and two sets of beads of the same color to represent other genes. Students may select any color except blue, purple, and "white" for the other genes. Ends are twisted together to complete the circle. The teacher will explain that the "white" bead represents the gene being developed and supply half the students with a mixture of white and UV beads. Students given the extra bead will open their plasmid model at the Lac Z' gene and insert the new bead between the blue beads. Students will add their plasmids to one of three bacteria. The teacher would explain that bacteria would be allowed to multiply. All models can be placed on the same table. Then the ones without the antibiotic resistant gene would be killed off with antibiotics. The bacteria models without the plasmid would be removed from the table. The teacher would then explain how the Lac Z' gene is used to determine whether the gene insertion was successful. The bacteria models in which two blue beads sit next to each other represent those organisms which do not have the inserted gene. These "Blue colony" bacteria are removed, leaving half the hosts. But which contain the desired gene? UV light exposure will activate the UV beads indicating which bacteria models "carry" the successfully implanted gene.

Background for Activity 3| Agricultural BioTech

Many plant hybrids are bred from different species, but one notable and unusual hybrid, *Tritcum aestivum*, was created by crossing different genera, specifically 10 different species in four generations. [38] This type of man-made breeding is called intergeneric crossing, but there are other artificial methods of plant breeding. Two other methods, embryo rescue and haploid breeding require laboratory intervention to sustain the resulting plants. In embryo rescue, a fertilized embryo created by mating unrelated plants, is raised in growth medium. These types of plants are usually not bred for seed, but serve as an intermediate step in hybridization. Another type of laboratory breeding is doubled-haploidy; this is when gamete cells are forced make a copy of the single set of chromosomes, in essence an embryo with two copies of each gene. This inbreeding process is used when a pure genetic line is desired quickly. [39] Mutation breeding occurs when plants are subjected to a mutagenic agent, either radiation or a chemical. If a mutation proves to be desirable trait, the resultant plant will be propagated conventionally. Linola™, an edible linseed oil is one of 1400[40] created through mutation breeding. However, spontaneous genetic mutations occur in the laboratory as well, and when a scientist deliberately cultures the spontaneous mutation, this is called a soma-clonal variation.

The next level of plant breeding, genetically modified organisms (GMOs) developed out of the genetics research done in the 1960s and 70s. The terms "genetic modification", "genetic engineering" or "transgenics" refers to the direct manipulation of an organism's genome through the insertion of foreign or synthetic genes. Organisms with this recombinant DNA are considered to be GMOs. [41] By 1976, bacteria had been genetically modified to produce insulin,[42] drastically reducing the cost of production. The first field trial of a genetically modified plant, an antibiotic-resistant tobacco,[43] was run in 1982.There is no doubt GMO research has benefitted millions of humans. The current controversy over transgenic organisms involves food. Today most of the Canola, Corn, Soybeans, Rice, Sugar Beets and Cotton used in over 70% of processed foods are GM[44]. Canola or "double-zero" rapeseed was modified to eliminate erucic acid which made it bitter and glucosinolates[45] which makes rapeseed toxic. The resulting plant can be used for cooking oil, margarine and animal feed. GM cotton is valued for its oil and as feed, in addition to its fiber. The versatile soybean is eaten green as a legume, used as animal feed, is a food additive, oil and is even used as a clothing fiber. The Round-up™ ready soybean, soybean 40-3-2, was bred to be immune to glyphosphate herbicides. Another GM soybean with a gene inserted from *Bacillus thuringiensis* expresses a protein that acts like an insecticide[46], but is not available yet. GM sugar beets comprise 95% of the entire U.S. sugar beet production. Two varieties of rice have been engineered; one to be herbicide resistant[47] and another that provides beta-carotene and iron. [48] However, there has been much resistance against GMO food crops for a variety of reasons, even when seed is provided free. Part of the reluctance to use GM crops might be the lack of understanding about the process of genetic modification.

Activity3| Fruit & Vegetable DNA Extraction

A model of DNA is still an abstract, a symbolic interpretation of the real thing. It is one thing to create a model of DNA another thing to actually see DNA with your own eyes. This activity provides a concrete experience for students, hopefully reinforcing the understanding that DNA exists in all living things and generating interest in science as a career. This activity is based on The University of Utah's *How to Extract DNA From Anything Living* lab. This lab will begin once again with a review of the research method and a review of the content using The University of Utah's *Learn Genetics* interactives. Students will be asked to make inferences that connect what they know about DNA, after which students will plan their experiment. Before the next class, Students will be given snack sized zip bags with chopped fruit or vegetables, water and salt at the start of the day. They will be asked to macerate these until their Media period. When they arrive, they will sit with other students who selected the same fruit or vegetable. The control sample will contain no fruit or vegetables. The students will combine their mashed fruit or vegetable and water with salt and detergent. The detergent breaks down the cell membrane, allowing access to the DNA, while salt helps the DNA clump. Each team will work cooperatively to strain the food. The strained mash is divided into test tubes or zip-snack bags. A pinch of meat tenderizer is added to release the proteins from the DNA. Finally, an equal amount alcohol is slowly added to the mash mixture. DNA should precipitate out of the mash and rise into the alcohol. Students will be able to see the DNA reaffirming the existence of DNA. Students may rinse the plant DNA with alcohol if they wish to keep it.

Background for Activity 4| Big6

This activity will pair the student product, an Investigation, with the metacognitive research method Big6.[49] Big6 has six steps: 1) Identify task and information needs, 2) Brainstorm all possible sources of information and select the best ones for the task, 3) Locate the information sources and using Reader Tools, access the information within each source, 4) Engage the 5 senses and extract the information, 5) Synthesize and organize the information, 6) Evaluate the product and the process. By breaking the research process into these smaller steps, students focus on only one aspect of the task at a time, producing better results.

Activity 4| Investigations

Both Big6 and Investigations are briefly reviewed. A variety of suggested topics will be displayed on the interactive white board as captioned images. These topics will include some GMO and non-GMO crops, scientists and career choices. Students may also suggest topics of inquiry. Students will sign up on the board under each heading and divide into small groups or choose to work as individuals. After each student has written a research question, students will brainstorm all possible resources and select the best 3 for their project. During the research process, I will conference several times with each student. Worksheets designed by Linda Hoyt are available in the book, *Make It Real: Strategies for Success with Informational Texts* and will be used as part of this process. Time will be provided in class and in their homeroom for these Investigations to be completed. Investigations will be posted, so students can view them during a gallery-walk.

Conclusion

Of the many problems caused by global climate change, food production and consumption is one that can be addressed on an elementary classroom level. In previous lessons, I explored other aspects of production and consumption. This season, I turned my attention to GMOs. Given all the other unnatural methods humans have used to modify their food crops, it seems strange that there is such an outcry against this method of crop production. Part of the difficulty is that there is no standard definition of GMOs. Another difficulty is determining what class of GMO our food products contain. Is it a GMO if the food itself is a GMO, such as papaya? Is the product processed from a GMO and contains denatured DNA, in the case of tofu? Or is it an extract of a GMO plant, containing no DNA at all, such as canola oil?[50] Where do we draw the line between what is considered to be GMO and what is not?

At this time transgenic crops have not noticeably increased yields, but scientists who are working on them are hopeful. The results so far have been mixed. For instance, the Flavr-Savr tomato and Golden Rice are two notable failures, rejected by consumers. Bt-corn, bred to resist rootworm, instead seems to have led to the development of rootworms resistant to Bt.[51] Given the current need for reliable sources of food and fuel on a planet where natural resources are not being renewed at the rate of consumption, it is unlikely that technique of genetic modification will be abandoned. Instead, we need to educate ourselves and our students to better understand the process, which may be one way to deal with global climate change.

Resources

Bibliography for Teachers

Brown, Lester R.. *Full Plenet, Empty Plates: The New GeoPolitics of Food Scarcity*. New York: W.W. Norton & Company,, 2012.

This book provides a concise overview of the political aspects of hunger.

Brown, Lester Russell. *Plan B 4.0: mobilizing to save civilization*. New York: W.W. Norton, 2009.

Lester Brown of The Earth Policy Institute monitors trends in politics, population, environment and climate. He offers a plan reverse the damage done by humans to their planet.

Dodds, Walter K.. *Humanity's footprint: momentum, impact, and our global environment*. New York: Columbia University Press, 2008.

Dodd covers both the science and the sociology of climate change. A good resource for understanding the human behaviors that have led to this disaster.

Eisenburg, Mike , and Bob Berkowitz, Berkowitz. "Big6 Skills Overview - Big6." Home - Big6. http://big6.com/pages/about/big6-skills-overview.php (accessed November 24, 2012).

This explanation of the Big6 research method is good for review as well as for teachers who are looking for a research method to teach. Site has lots of additional teaching resources.

Hoyt, Linda. *Make it real: strategies for success with informational texts*. Portsmouth, NH: Heinemann, 2002.

A quick reference for teachers that briefly reviews a number of strategies to teach using nonfiction texts.

Kreuzer, Helen, and Adrianne Massey. *Biology and biotechnology: science, applications, and issues*. Washington, D.C.: ASM Press, 2005.

An excellent and (more importantly) readable science textbook on the subject of biotechnology.

McHughen, Alan. *Pandora's picnic basket: the potential and hazards of genetically* *modified foods*. Oxford: Oxford University Press, 2000.

If only have time to read one book on the subject, read this one. McHughen makes a difficult subject understandable and tries to present without bias information about GMOs.

Moline, Steve. *I see what you mean: visual literacy K-8*. 2nd ed. Portland, Me.: Stenhouse Publishers, 2012.

Moline discusses the importance of using visual literacy techniques in teaching.

"PCR Virtual Lab." Learn.Geneticsâ„¢. http://learn.genetics.utah.edu/content/labs/pcr/ (accessed September 29, 2012).

Interactive that walks students through the steps of DNA extraction.

Great Pacific Media. "Plasmids | Genetics | Biology - YouTube | Biotechnology: Engineering Genomes." YouTube. http://youtu.be/GNMJBMtKKWU (accessed November 24, 2012).

A video clip that shows plasmid replication in bacteria. For younger students, you will wish to play the video without audio and provide your own explanation.

Vasquez, Jo Anne, and Michael W. Comer. *Developing visual literacy in science, K-8*. Arlington, VA: NSTA Press, National Science Teachers Association, 2010.

A great resource book for teachers about the importance of visual literacy.

Reading List for Students

Biskup, Agnieszka, Cynthia Martin, and Bill Anderson. *Understanding global warming with Max Axiom, super scientist*. Mankato, Minn.: Capstone Press, 2008.

This is a really good explanation of global warming, explaining both concepts and causes. The colorful graphic novel format will appeal to boys.

Cole, Joanna. *The magic school bus and the climate challenge*. New York: Scholastic, 2012.

A familiar cast of characters offers a friendly introduction to the subject.

Green, Jen. *Genetically modified food*. North Mankato, MN: Stargazer Books, 2006.

This is almost the only book available on an elementary school level for students. It is biased towards genetically modified foods.

Keyser, Amber, Tod Smith, and A. Milgrom. *Decoding genes with Max Axiom, super scientist*. Mankato, Minn.: Capstone Press, 2010.

Max travels back through time to meet Gregor Mendel! A good way to cover basic genetics. Keyser brings us back through time to talk about agriculture as well as careers.

Prokos, Anna. *Guilty by a hair!: real-life DNA matches*. New York: Franklin Watts, 2007.

A gory book for upper elementary and middle-school students who love police detective books and television shows that uses true-crime examples.

What Traits Are in Your Genes (Series)

Boothroyd, Jennifer. *Facial features: freckles, earlobes, noses, and more*. Minneapolis, MN: Lerner Publications Co., 2013.

Boothroyd, Jennifer. *Vision: nearsightedness, farsightedness, and more*. Minneapolis: Lerner Publications Co., 2013.

Silverman, Buffy. *Unusual traits: tongue rolling, special taste sensors, and more*. Minneapolis: Lerner Publications, 2013.

Silverman, Buffy. *Body parts: double-jointedness, hitchhiker's thumb, and more*. Minneapolis, MN: Lerner Publications, 2013.

Silverman, Buffy. *Unusual traits: tongue rolling, special taste sensors, and more*. Minneapolis: Lerner Publications, 2013.

A new series which is not yet available that may provide good information.

List of Materials for Classroom Use

Activity1| Hasty Plants

Hasty Plant kit from Carolina Biological Supplies
Grow Light or window with 6+ hours of sunlight
Water
Extra 1-pint containers
Masking tape
Permanent markers

Activity 2| Building a DNA Model

12” Chenille stems or pipe-cleaners
6 colors of pony beads
Instruction sheets, available at http://www.raftbayarea.org/ideas/Modeling%20DNA.pdf

Optional Activity 2| Building Plasmids

Construction paper
Chenille stems
Pony beads including blue, white, purple and UV sensitive

Activity3| Fruit & Vegetable DNA Extraction

DNA Necklace kit from Carolina Biological Supply, or
Snack size zip bags
Strawberries, cut into 1” pieces and defrosted frozen peas
Dawn dishwashing liquid
Salt
Water
Cheesecloth or coffee filters
Funnels
Alcohol, rubbing
Meat tenderizer

Activity 4| Investigations

Worksheets from *Make It Real: Strategies for Success with Informational Texts*
Ledger size copier paper
Pencils
Markers
Rulers

Access to reference books or internet

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