Curriculum Units by Fellows of the National Initiative
2013 Volume VI: Genetic Engineering and Human Health

Effects of Genetically Modified Organisms on Agriculture

Curriculum Unit 13.06.04, published September 2013
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Rationale

It has always been incredibly difficult to convince students why they should be interested in chemistry because they do not see how it is pertinent to them. Having grown up on a fruit farm, I have seen the direct benefits of chemistry—particularly using herbicides and pesticides, which allow farmers to harvest a better quality crop. The argument for using Genetically Modified crops is very similar to the argument for the use of herbicides and pesticides. This unit will tie the foods we eat and the choice to consume genetically modified crops to basic concepts of both chemistry and biology.

I have witnessed the obliteration of crops by insects, fungi, and viruses that do not react to the chemicals being used. Farmers rely on their crops for their income, and with poor or withered crops there is little or no income to gather. I believe that my students will be interested in this topic because it does affect their everyday lives regardless of if they know it or not. The foods we eat affect who we are as human beings, as research continues, scientists are linking genetically engineered products to multiple diseases and disorders in humans. This knowledge enables consumers to make important choices regarding the foods they choose to eat.

In today's world there seems to be a growing trend of eating healthy; but, what does that really mean? It is understood that we should eat more servings of fresh fruits and vegetables balanced with a proportioned protein while limiting fats. Going to the grocery store used to be a simple job; you made a list, went to the store, purchased your items and went on your way. The "healthy" foods are almost always the very first section at the grocery store when you walk in the door, but you no longer have just one choice of what to buy. There are multiple items that look similar, but may have different labels. Foods can be labeled as natural, organic, USDA organic, genetically modified, no MSG, gluten free, or heritage even though standards vary as to what each word really means. When most consumers buy produce at the grocery store they choose what to buy based on looks. In our minds we assume that what looks the best is the best for us, but this is not necessarily true.

Currently there are no federal guidelines enforcing descriptive labels on foods, so how can you figure out what it is you are eating? Many health conscious consumers choose to actively look for products that are labeled as being organic, meaning they have not been treated with pesticides or herbicides; thinking that they are getting a higher quality product. Amanda Hermes wrote an article helping differentiate between the identification of foods with these different labels. [1] The article describes the subtle differences between the various labels and how they are regulated. Many consumers assume that products which have been genetically modified will be better for them, but the health benefits of genetically modified organisms (GMOs) are not clear.

When companies genetically engineer seeds the hope is to increase yield, drought tolerance, salt resistance, and enhance nutrition; however, studies on the effectiveness of these modifications is conducted by the companies performing the modifications. These studies are short lived, and most alarmingly results do not have to be released to the public. Independent scientists, of course, are interested in testing the validity of the claims made by manufacturers about the "better" quality of the GMO products, but cannot conduct their own tests due to fear of litigation. [2]

In this unit, my idea is to have students look at the foods they eat, especially prepared foods, and think about the chemicals that are part of those foods. When looking at where foods come from, it is becoming more and more difficult to find foods that do not contain genetically modified organisms. Considering socioeconomic factors and the higher prices of organic foods and foods without GMO's, it is clear to see how inner-city kids have higher exposure rates than the students in the suburban areas. I think it is important for students to acknowledge where food comes from, and how the foods we eat affect our health.

When I have asked students where their food comes from, I have been told from the store, but even working with high school students it is difficult to get a more precise answer than that. When pressed I am usually told that food comes from a factory, and when asked where the factory got the food they just roll their eyes and say who cares. Having grown up on a farm and having the privilege of growing my own food, at least some of it, I could not understand how there was this huge disconnect between growing crops and getting them to the grocery store. There are bumper stickers that say no farmers no food, this made sense to me because of my background, I had never imagined that my students did not have knowledge of their food sources.

Objectives

My goal is to layer chemistry and biology concepts with thinking about DNA and how it can be modified prior to becoming the foods we eat. What better way to get students interested in the particle level other than thinking about what happens in our bodies? Each cell in our bodies contains DNA molecules, which are combinations of the same atoms that form water, carbon dioxide, and all other molecules. Just like simple chemical reactions which get discussed in general chemistry classes it is chemical reactions that happen in order for our DNA to make us who we are. The intent is to get students to make the connections between the biology they studied in the previous school year to some of the chemical reactions happening in their bodies to make them who they are.

I want my students to look at where their food comes from: that is, how the food we eat gets to the grocery store. From a cursory survey of my students from the previous school year many of my city students do not regularly consume fresh fruits and vegetables and have never actually thought about where those fruits and vegetables come from. They are provided with cheap prepared foods with no regard for nutritional value and have no experience with actually growing any fruits or vegetables of their own.

My hope is to not only get students to think about where our food comes from but also what it is that makes us who we are. Having grown up hearing, you are what you eat; I presume the connection there will be fairly simple to make. I also want to consider how each person has a unique DNA sequence, and how that sequence defines us as human beings. Much of our sequence is very similar, but just a tiny variation in that sequence can have drastic repercussions. By giving students the opportunity to grow and compare their own crops we will have a simple conversation starter to pique interest: the crops that are grown are not the same just as not all humans are the same, even though both the crops and we as people are made out of atoms of the same elements.

Scientists who understand DNA sequencing have been able to identify genes within chromosomes and link them to specific traits. Once they have identified a trait and where to find the genes that control it, they were also able to identify a similar trait with subtle differences from another DNA sequence. After years of research scientists have been able to modify the genetics of the DNA in plants to create genetically modified crops with preferred properties. Scientists unravel a strand of DNA, send in an enzyme to break apart the original strand, and then put it back together with a new piece of DNA linked in. This is a very basic description of how scientists change heirloom crops into GMO crops. The issue of modifying crops is fairly controversial and will be discussed by students at length specifying the following arguments:

Pros

One argument for GMO crops is that we can increase the nutritional value of crops merely by changing part of a genetic sequence but maintaining the other properties of the fruit or vegetable. Some advantages for GMO crops are increased yield, drought tolerance, salt resistance, and enhanced nutrition.

A central idea behind GM crops is that more crops can be grown in harsher conditions using less land: this could be an answer to world hunger. The world population is currently around 6 billion people but continues to grow. The expectation is that the world's population will peak around 10 billion. According to John E. Smith in *Biotechnology* there will need to be a substantial increase in food production, with 80% coming from developing countries, yet introducing less than 6% of new virgin soil for cultivation. Thinking back to the 60's and 70's, when faced with a similar problem, the answer scientists came up with was to increase the use of fertilizers, biocides, and irrigation. (John E. Smith pg 133) [3] It is no longer acceptable to keep spraying the foods we eat with chemicals that may be harmful, so the alternative is to change the chemistry within a plant so that the plant and not the environment in which it grows is what changes.

Agriculture continues to be the world's largest single industry in advanced societies such as the US contributing 20% of the total gross national production (John E. Smith pg 134). In order to survive as a human race, we must rely on agriculture to provide sustenance, in turn; agriculture must rely on technology to achieve productivity and profitability (pg 134.) Many countries do not produce enough food to be self sufficient for many reasons such as a lack of good agricultural practices, hostile or changing climate, or political instability. If a country is too poor to take advantage of biotechnology and new practices, companies like World Bank and European Economic Community chose to help them catch up with the times (pg 134). [4] The food has to come from somewhere; the issue is if it is ethically and morally right to modify the DNA of plants in order to produce it.

Cons

It is not clear that GMOs are safe, particularly because the genetic modifications may migrate. There are many questions about the unintentional migration of the genetically engineered crops, which inadvertently results in the loss of biodiversity. Historically these changes have been driven by evolution which is where some of the controversy comes into play. According to Van Den Bergh and Holley, once differences in plants are lost the resistance against insects is reduced, which may lead to an insect plague or disease. Non-targeted species may also be affected by outcrossing from domesticated species [5] (page 8-9). Seed companies conduct short term studies on the effectiveness of their creations but do not conduct long term studies to fully understand the repercussions of using genetically modified crops.

There needs to be comprehensive studies on pollen drift, gene flow, weed resistance, cultural imperialism, predatory multi-nations, and increasing popular mistrust [6] . Currently 50% of the world's GMO's are grown in the United States whereas many other countries have banned the use of GMO's. Some scientists are unable to conduct experiments to fully understand the effects of GMO's due to fear of litigation. If we are going to choose whether to purchase genetically modified foods then there has to be a way to become informed consumers.

Other issues that come into play with GMO crops include the creation of superbugs, changes in biodiversity, and the creation of allergens. A superbug occurs when bacteria or viruses have developed a resistance to the chemicals available to treat them. One superbug that has recently gotten a lot of attention is MRSA, methicillin-resistant Staphylococcus aureus, which is an antibiotic resistant staph. According to Maryn McKenna in her book *Superbug*, the story of MRSA is the story of how we took antibiotics for granted, and failed to plan for the creative survival tactics of bacteria. Maryn also explains how our willingness to trust technology helped lead to epidemics such as MRSA. [7] Scientists have to continually create new solutions to changing problems like MRSA and others which may develop in the future, possibly as a result of using GMOs.

Classroom and School Environment

This unit is specifically written for 10 th grade academic chemistry classes at an urban public high school. I currently teach at Carrick High School in Pittsburgh Public Schools where my students are 38% African American, 7 % Multi-racial, 53 % Caucasian, and 2 % Other. There also happens to be 76% of students who receive a free or reduced lunch. As with most city schools, students struggle to pass standardized tests (Pennsylvania System of School Assessments): in the 2011-2012 school year 46% of students scored basic or below basic in reading and 66% scored basic or below basic in math. Needless to say city school students are not always interested in the content presented to them. Students are often forced to take academic chemistry even though many choose professions that do not pertain to the science field. In order to help close the Achievement Gap teachers do everything in our power to ensure that all students learn. Specifically in chemistry we are always trying to get students to think at the particle level; but, the world we live in is macroscopic and doesn't acknowledge the particle nature of matter.

It has always been incredibly difficult to convince students why they should be interested in chemistry because they do not see how it is pertinent to them. In order to spark student interest we need to step back and show students the information is relevant. For example, how do these tiny particles interact with each other in order for DNA to exist and essentially make our lives what they are? By using a hot topic as an example of how chemistry is important we may get more students interested in making a difference and actually continuing their education in the sciences.

Standards

The Next Generation Science Standards and the Common Core standards encourage teachers to embed rigor into their curricula: this unit it specifically designed to meet the following Next Generation Science Standards: ETS1.B and HS-ESS3 [8] . The intention is for students to be given a choice of either supporting genetic engineering or not given a range of criteria. They will need to analyze factors such as cost, safety, reliability, and aesthetics, along with social, cultural and environmental impacts. The effects of genetic engineering will impact the environment and biodiversity. Students will need to acknowledge both the pros and cons of consuming genetically modified crops and use their own judgment to create a position paper stating if they support the continued use of genetically modified crops, and specifically back up their opinion with research. This process will help them model the behaviors of scientists and develop their skills at backing up their opinions using data.

Connecting to Chemistry

In general chemistry we spend a lot of time talking about atoms and what makes them either stable or unstable. Just like humans, atoms want to use the smallest amount of energy possible. In order to accomplish this they tend to form bonds with other atoms to form molecules or formula units. Atoms can either transfer or share electrons in addition to being attracted to opposite charges. In general scientists refer to atoms bonding ionically, covalently, or forming hydrogen bonds. When forming ionic bonds electrons are either given away or taken from another atom. Certain atoms, specifically metals, prefer to donate their outer shell electrons, valence electrons, in order to obtain a pseudo-noble gas configuration. Unlike metals, nonmetals tend to have more valence electrons and prefer to gain extra electrons becoming negatively charged in order to attain a pseudo-noble gas configuration. Atoms are willing to gain or lose electrons to become similar to noble gases because they are the most stable due to having a full octet, or 8 electrons in their outer shell. When an atom has a full outer shell it is most stable and no longer wants to gain or lose electrons.

After atoms have bonded they are no longer transferring electrons but are still subject to the electrostatic forces between their subatomic particles. Each element is assigned a numerical value to represent how badly they want another electron in their outer shell, which we refer to as their electronegativities. Metals tend to have low electronegativities representing how easily they are willing to give up their valence electrons, whereas nonmetals have higher electronegativities because they are closer to having a full octet so they gain extra electrons. It would be simpler if all atoms either gained or lost electrons, but that is not the case. If two atoms are in the same vicinity and want to bond because the nucleus of one is attracted to the electron cloud of the other, it is not necessarily the case that they can bond ionically. If the atoms have similar electronegativities they end up sharing their valence electrons so that each atom has a complete octet some of the time. Just like when two siblings are responsible for sharing a vehicle, there is usually one who is stronger, more electronegative, than the other, and that atom will obtain the shared electrons more often than the weaker atom.

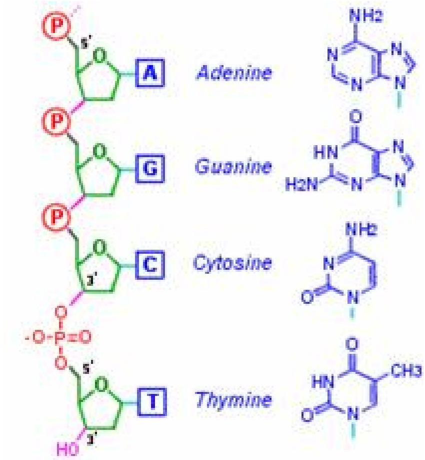
Once atoms have bonded they do have lower energies and are more stable, but are not necessarily done acting or reacting to the other atoms or molecules around them. Keep in mind that all of these electrostatic charges around each other will not be ignored. In ionic compounds the ions come together to form crystal structures nicely aligning the positive and negative charges evenly forming a strong stable crystal structures. When atoms bond covalently instead they have to share the electrons creating dipoles or partial charges within molecules. Bonds are labeled as polar when the electrons are pulled more in one direction, towards the more electronegative atom, than another. When a molecule has multiple atoms the bonds between those atoms can either cancel out their polarities or overall pull the electrons more in one direction than any other resulting in a polar molecule. Similar to how ionic compounds line up their cations (positively charged atoms) and anions (negatively charged atoms) the dipoles within covalently bonded molecules align themselves as well.

After atoms have formed compounds they may still change again in order to become more stable in a chemical reaction. In general chemistry we tend to discuss combination, decomposition, single replacement, double replacement, and combustion reactions. The overarching idea to keep in mind is that in a chemical reaction atoms just rearrange. When teaching chemistry we are always trying to get students to think at the atomic or molecular level and to think about the interactions and reasons why changes occur.

Previously I alluded to cations and anions, but there are also polyatomic ions which are a small group of atoms covalently bonded but acting as a group which has a net charge. Traditionally general chemistry classes only talk about the most basic molecules but this may be preventing students from pursuing their curiosity about the chemical reactions that happen within our own bodies and in the foods that we eat. If we specifically think about DNA (or deoxyribonucleic acid) the same forces that bring atoms and molecules together make our DNA align itself into a specific structure or shape. DNA is composed of two strings of long molecules covalently bonded together; the two strings are additionally connected by hydrogen bonds creating a double helix matrix of molecules. Keep in mind that the forces bringing these molecules together are those same positive and negative charges originally bringing together ions to form ionic bonds.

Our DNA defines us as humans. These simple chemistry concepts work together in the formation of DNA. DNA is a double stranded polymer where there are two rails which are covalently bonded then becomes more stable when hydrogen bonds are created between the two rails. There are four monomers which are involved in the coding of our DNA; these monomers are adenine, thymine, cytosine, and guanine. These monomers always partner in a specific way, adenine always pairs with thymine, and cytosine always pairs with guanine. The order of these pairs determines the traits that our genes express.

If you are trying to give a plant a heartier root stock, you would need to know where to find the DNA of the plant cell and more specifically what part of the sequence when activated determines how the roots grow. Plant cells are different from animal cells in that they have a rigid cell wall which is harder to get through than a cell membrane. When looking at the rails of the ladder or the backbone of the DNA polymer we notice that the molecules have aligned themselves so that you see ribose then a phosphate in a repeating pattern as shown in the picture.



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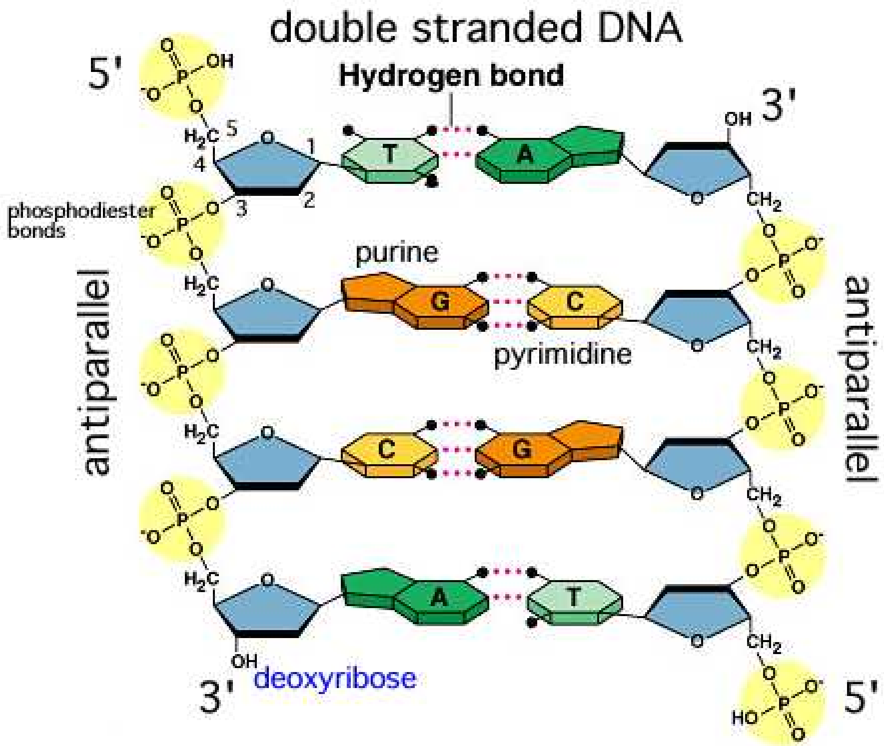

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In order to genetically modify plants scientists must first identify which characteristics in a plant they want to modify. This is also important because the new sequence to be inserted must be able to travel into the nucleus where the plant DNA is found. In order to make pieces of DNA small enough to use scientists use plasmids which are small circular pieces of DNA. A restriction enzyme is used to cut the DNA into small pieces. Once the plasmid containing the desired gene is isolated scientists add a promoter, the desired gene sequence, and a terminator to the original sequence. The new sequence is then inserted back into the organism where the promoter initiates transcription for the new DNA sequence.

Scientists can actually change the DNA sequence by cutting the original chain and sending in a new sequence to modify the gene, which can then be expressed in its new form. Just like how H_2O, water, and H_2O_2, hydrogen peroxide, are made of the same pieces, having one extra particle makes a huge difference and completely changes the properties of that molecule. After identifying the part of the sequence that determines root properties the scientist would insert a replacement sequence with the DNA sequence from another plant with the desired property or a synthetic version of the desired sequence.

Differences in the genetic sequence will modify the characteristic of the plant's genome. When replacing an original section of DNA with a new sequence I am reminded of a single replacement reaction where you are literally replacing one element or polyatomic ion with a different one in order to change the properties. I think this mechanism clearly relates the two procedures even though the levels of complexity are removed from this scenario.

Strategies:

Students will begin by creating a concept map of their perception of what makes them who they are while thinking specifically as a scientist. I expect answers to vary and that many concept maps will include items such as their personality, style, environment, experiences, food, biology and chemistry. Students will then find an elbow partner to see if they have any similarities or differences. This will lead to the class charting what they feel are the most important items from their charts. The discussion will be guided towards thinking about the foods we eat, and the biology and chemistry behind it.

Students will be reading articles emphasizing the pros and cons of genetically modified crops and then they will interact with several case studies from the National Center for Case Studies. Students will work through two case studies one called Frankenfoods and the other called Tougher Plants [11] . These two case studies were specifically chosen to ensure that both the pros and cons of genetically modifying plants are thought about. Each case study will have students working in diverse groups in order to encourage conversations between students with varied home lives. Students will then work with their groups to create a chart of all factors they believe should be considered when deciding if crops should continue to be genetically modified or not.

The positive effects of genetically modifying plants that they will be presented with are needing less water to grow, using less chemicals to keep crops healthy, higher production rates, more aesthetically pleasing, higher nutritional values, and allowing farmers a larger profit margin.

On the other side the negative effects will include higher produce prices for those who choose to eat non-modified produce, have a different taste, the creation of superbugs, unintentional contamination of non-modified foods, lack of labeling regulations, creating new allergens, and the loss of biodiversity. The fact is that no one knows what the results of continuing to create genetically modified plants will be. There are some very valid concerns especially when the original intent of the created plants causes more problems than expected.

The final article students will be given before the trip to the farm will be "GMO Crops Mean More Herbicide, Not Less" written by Beth Hoffman for Forbes Magazine. This articles states that the corn and soybeans being planted were genetically modified to withstand herbicides; however, there are two recent studies showing that the reduction in herbicide use only lasted a few years. After the first few years the amount of herbicides being used multiplied seven fold. This in fact does not lead to the farmer making money but again costs the farmer more to produce the crops which in the end cause consumers to pay more at the grocery store. In this particular case the only people making money are the companies producing the genetically modified seeds and the companies providing the herbicides. Along with needing more chemicals to treat crops to ensure production there are also many articles cautioning about the emergence of superbugs. Nature still follows the survival of the fittest mantra, so if crops become resistant to a certain pest, those pests will evolve to come at the crops in another way.

Since many city students have never had a garden nor have family members with a garden I find it necessary for them to actually see the growth of zucchini plants that have been genetically modified as well as the growth of non-modified zucchini. Activity 3 is given as one example of a data collection chart for students to use as a template. They will need to create their own chart and determine what characteristics of the plants and zucchini they deem important. I expect that some students will choose to find the mass of the zucchini produced where as others will focus on aesthetics of the plants and products. It is imperative that they be very clear on how to monitor the experiment to make sure that the plants are given the same opportunities to grow. As with any experiment using the scientific method they need to identify one and only one variable, in this case it is the seeds being modified or not. The data collected will be useless if the other conditions of the experiment are not kept the same.

Students will also be asked to collect data to compare genetically modified zucchini to non-GMO zucchini. This data is to be considered when creating their position paper and used as evidence to back up their thoughts. Students will also be asked to reflect on whether their opinion has changed throughout the unit and what changed their minds. I would like them to collect data on the plants, the number of zucchini produced, and the sizes and quality of the products. Students will also have an opportunity to determine if they can differentiate between the tastes of the products. Students will also have access to records of the pesticides and herbicides used, if any.

I would like students to identify how many GM products they consume and what steps they can take to predict how much they are exposed to GMO's. If students can raise enough money to pay for a bus, we will take a field trip to Orton's Fruit Farm in North East Pennsylvania where students will be able to see how fields are planted and ask questions about how GM crops have affected small farm owners. The experts in this case will be my father and brothers, who currently run a hundred acre farm. The farm is currently used to grow 75 acres of apples, 15 acres of grapes, and 10 acres of various vegetables, all to be sold on fresh market. Students will be shown how crops are treated with herbicides and pesticides, and see the damage to crops when not treated. I also think it is important for them to realize that farmers do not have an income if they have no crops to sell, so if the produce is small, ugly, or bruised the farmer's income is greatly diminished.

At the farm, my brothers Matt, Mike, and Mark pull out the different equipment used to prepare the soil, till it, and maintain growth including the use of herbicides and pesticides. There is a very detailed process of keeping track of how much chemical is being used and where it is being used. There are classes that farmers must attend and tests they must pass in order to have the right to use these chemicals. Just like teachers have to have continuing education credits, so do farmers. My brothers will also explain the need for irrigation and show how the pipes are moved in order to rotate which crops are being watered and when.

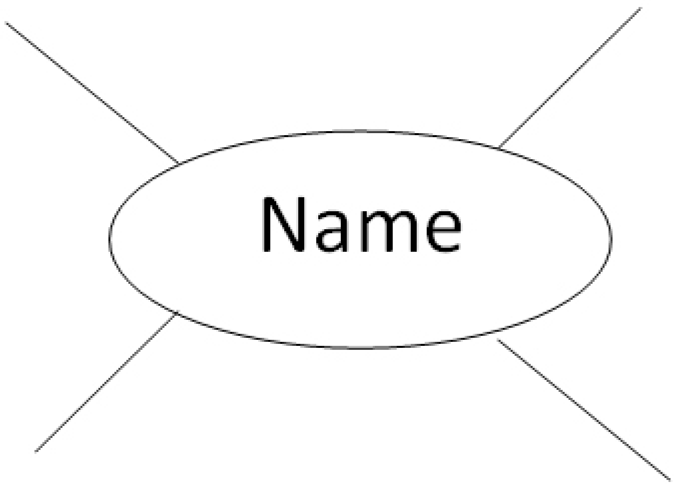
Students will inevitable ask questions like why they are not irrigating during the day when the sun is out. Plants are not watered during the day because the water is drawn out of the leaves too quickly and the leaves burn, so they get watered either early in the morning or in the evening. The first time I took students to the farm we showed them several man-made ponds used for irrigation and they were amazed at how I grew up with a lake on our property. Since this is a huge misconception that I did not anticipate, the next time I took students to the farm we also made a stop at Lake Erie which is only 2 miles North of the farm. I explained that Canada is only 40 miles on the other side of the lake and kids I went to high school with swim it each year. Students were in awe and asked if they were at the ocean. I had always taken my life experiences for granted and had no idea how not growing up around an actual lake throws what we learn early on in geography class out of proportion. The students had this awesome new experience and shared that with their friends once we returned home. My hope is to again incorporate a trip to the farm so that they can see the differences in the crops.

My parents also have a fresh market store and a wholesale business where students will see where fruits and vegetables are stored prior to arriving at a grocery store. While on the farm we feed them and they can taste the difference between having fresh fruits and vegetables compared to the imported fruits that are picked weeks early so that they can travel to the grocery stores where they are sold with limited damage since they are not ripe. My students never understood why I said I would not purchase fruits like apples and peaches from a grocery store until they tasted the difference for themselves. Even three years after I took the first group of students to the farm, I saw an old student at a Pirates baseball game and he asked me if I had any apples. This touched my heart because I knew I shared an experience that will never be forgotten.

After visiting the farm and getting a clearer vision of agricultural practices students will have another article to read, and then will need to put together a position paper. In order to help students organize their thoughts I have them use the claim-evidence-reasoning model in science. Students tend to get bogged down when reading non-fiction and get confused about what to do with the text. I find posing a question for them to specifically answer helps them write as if they are telling another person why they believe they have the correct idea. It is not my concern about which claim they make, I am more interested that they make an appropriate claim and choose evidence that actually backs up the specific claim that they are trying to prove. I consistently find myself telling my students that if they were scientists they would always be trying to prove something and no one is going to believe them just because they say something. Once students have put together a few scientific explanations they tend to do very well with both the claim and listing appropriate evidence, but struggle with the reasoning. I feel the reasoning is the most important part; this is the thought behind why you chose that specific piece of evidence to support your claim. I think that if you have a personal stake in what you are writing about or explaining that you make a more compelling argument. This is an additional reason I chose to pose a question that directly relates to the everyday lives of my students. I don't think it gets more personal than thinking about the foods you put into your body and the implications of how our lives can be changed by the recombination of tiny molecules.

Activity 1: Concept Map

Directions: Thinking like a scientist what is it that makes you who you are? Be specific and make connections where you feel there are overlaps. Add more lines as needed.



Activity 2: Create a list of the pros and cons of using genetically modified crops then decide if you are for or against the continuation of genetically modifying crops. You will use this list for another assignment.

Pro	**Con**

Make a claim that you will defend in a position paper. Your claim will be the beginning of your scientific explanation. Your position paper will begin with a claim, then you will add evidence from the texts you have been reading, and then explain why the evidence you chose backs up your claim.

Sample Claim: Eating fresh fruit is a healthier choice than snacking on a candy bar.

Claim:

Activity 3: Sample Data Collection Template

Characteristic	Modified 1	Modified 2	Non-modified 1	Non-modified 2
Height of plant				
# zucchini picked				
Width of largest leaf				
Color of leaves				

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