**The relationship between agriculture and technology**

**Pillar 5 C. Identify the primary benefits and concerns pertaining to biotechnology**

 (9th – 12th Grade)

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| **Website**: <https://geneed.nlm.nih.gov/topic_subtopic.php?tid=41&sid=43> , <https://www.usda.gov/topics/biotechnology/biotechnology-frequently-asked-questions-faqs> , <http://www.pbs.org/wgbh/harvest/> , <http://www.apsnet.org/edcenter/K-12/TeachersGuide/PlantBiotechnology/Pages/DNA.aspx> **Hands On**: <http://www.actionbioscience.org/biotechnology/lessons/altierilessons.pdf> <http://www.agclassroom.org/teacher/matrix/lessonplan.cfm?lpid=86&grade=9&author_state=0>  |

**Evaluating Perspectives About GMOs**

**Purpose**

While many view genetically modified crops as a promising innovation, there is controversy about their use. This lesson provides students with a brief overview of the technology, equipping them with the ability to evaluate the social, environmental, and economic arguments for and against genetically modified crops.

**Materials**

**Interest Approach and Activity 1:**

* Internet and video projection capability
* *GMO* PowerPoint
* *Food Label Cards*, 1 set per group
* *Critically Thinking GMOs* handout, 1 per student (this handout will be used throughout the lesson)

**Activity 2**:

* *GMO Fact or Fiction* PowerPoint or [Kahoot](https://getkahoot.com/) app and electronic devices

**Activity 3:**

* Ball (8" or larger plastic ball or an inflatable beach ball)
* *Crop Supply and Demand Challenge Cards*, 1 copy per class

**Essential Files (maps, charts, pictures, or documents)**

* [GMO Fact or Fiction PowerPoint](http://naitc-api.usu.edu/media/uploads/2016/07/15/GMO_Fact_or_Fiction_1.pptx)
* [GMO PowerPoint](http://naitc-api.usu.edu/media/uploads/2016/07/15/GMO_PowerPoint_1.pptx)
* [Critically Thinking GMOs handout](http://naitc-api.usu.edu/media/uploads/2016/03/30/Critically_Thinking_GMOs_handout.pdf)
* [Food Label Cards](http://naitc-api.usu.edu/media/uploads/2016/03/23/Food_Label_Cards.pdf)
* [Crop Supply and Demand Challenge Cards](http://naitc-api.usu.edu/media/uploads/2016/03/23/Crop_Supply_and_Demand_Challenge_Cards.pdf)
* [GMO Crop Spotlight Sheets (optional activity)](http://naitc-api.usu.edu/media/uploads/2016/03/01/GMO_Crop_Spotlight_Sheets.pdf)

**Vocabulary**

**GMO:** genetically modified organism

**Acrylamide:** a chemical substance which forms in starchy foods after high-temperature cooking processes such as frying, roasting, and baking

**Crossbreeding:** selectively breeding two plants or animals of different breeds or cultivars to produce a superior offspring sometimes called a hybrid

**Gene:** a region of the DNA that encodes a protein or part of a protein

**Genetic engineering (GE):** process of directly modifying an organism’s genes using biotechnology to produce desired traits

**Hybrid:** the offspring of two plants or animals of different species or varieties

**Inbreeding:** selectively breeding closely related plants or animals in an effort to isolate and perpetuate a desired trait

**Mutagenesis:** a method of selective breeding in plants where seeds are exposed to chemicals or radiation to promote DNA mutations that could result in developing new traits in offspring plants

**Selective breeding:** process by which humans use animal or plant breeding to selectively develop particular traits in an offspring; also known as artificial selection

**Transgenic:** containing a gene that has been transferred from one organism to another and acts as a synonym for genetically modified

**Did you know? (Ag Facts)**

* 89% of the corn grown in the United States in 2015 was produced from seed varieties developed through genetic modification technologies.1
* As the use of genetically engineered crops has risen, the use of insecticides has decreased.2
* As the use of genetically engineered crops has risen, the use of herbicides has increased.2
* Many science organizations throughout the world, including the World Health Organization, find genetically modified crops to be safe for consumption.3
* Although significant science supports the safety of GM foods, many consumers are skeptical and perceive that non-GM foods are healthier.4

**Background Agricultural Connections**

This lesson does not detail the process of genetic engineering. Students should have a basic understanding of DNA, genetics, inheritance, and selective breeding to conceptually understand genetic engineering.

**Interest Approach – Engagement**

1. Project the first slide of the *GMO PowerPoint*. Tell your students to imagine they are grocery shopping. As they are selecting their food items they begin to notice all of these labels. Hold a short class discussion about the labels and discuss what they might mean. Move on to slide two. Ask students if they have seen either of the two "non-GMO" labels. Ask students, "Are there any common food labels that *could* be misleading or meaningless?"
2. Divide your class into small groups and give each group one set of the *Food Label Cards*. Instruct your students to look through the cards and tell you what words are contained on every food package. *(non-GMO)*
3. Explain to your students that within their stack of cards there are 18 foods with labels that are "imposters." Explain that an *imposter* is something that is disguised. Some of the foods in their stack of cards are *imposters* because the ingredients in these foods are derived from crops that have currently not been genetically modified. (Allow students time to separate their cards. Use slide three as a visual).
4. Project slide four of the GMO PowerPoint. Use the slide to explain that there are currently only 10 crops that have been genetically modified and approved for commercial use by farmers. Therefore, only foods containing these ingredients even have the possibility of being genetically modified. Once you have listed the crops, ask the students if they need to make any changes to their piles.
5. Give students the correct answers and list which foods *could* have GM ingredients and which foods could *not* actually be genetically modified because no GM form of the food exists.
	* **Foods that *could* have GMOs:** Soymilk (soybean), cinnamon crunch cereal (sugar could be from sugar beet), rice milk (canola oil), wheat bread (sugar and soybean oil), pita bread (sugar with unspecified source, canola/soybean oil), and margarine (canola and soybean oil).
	* **Foods that currently do *not* have GMOs:** 2% milk, graham crackers, clementines, yogurt, mango baby food, banana baby food, flax seed, rye flour, wheat flour, sweetener, sugar (this label specifies it is from sugar cane plant), shredded wheat, tea, coffee beans, rice, orange juice, sour cream, and cottage cheese.
		+ **Note to teacher:** The two primary sources of table sugar are the sugar cane plant and the sugar beet. Many food labels list "cane sugar." Cane sugar or sugar cane is not an approved GM crop. If it does not specify, it could be from either plant. It could be genetically modified if it came from a sugar beet.
6. Introduce the lesson topic to the students by helping them see that as a consumer, every time they enter a grocery store they may have the opportunity to buy (or not buy) a GM food. In this lesson we will be talking about what GMOs really are and why some food companies are labeling their foods even though their food product could not possibly contain GMOs.

**Procedures**

**Activity 1: GE and Me**

***What is genetic engineering and why does it matter?***

1. To begin, students will be learning what GMOs *are* and what they are *not*. (Students should still have their *Food Cards* after completing the *Interest Approach* section of the lesson.) Give each student a copy of the handout *Critically Thinking GMOs*. Have students fill out the Venn Diagram located on the first page of the handout as you go through *Activity 1*. Remind them along the way to make notes on this handout.
2. Show the video, [*How Are GMOs Created?*](https://www.youtube.com/watch?v=2G-yUuiqIZ0)Prior to showing the video, ask students if they have ever eaten papaya or drunk papaya juice. Show students the picture of the papaya and the papaya tree and explain that it is a tropical fruit grown mostly in Hawaii. Prepare students for the video by explaining that they will be learning how GMOs are created using the example of the papaya.
	* **Optional:** To further illustrate what a GMO is, show the inFact video [*The Unpopular Facts about GMOs*](https://www.youtube.com/watch?v=fIgqXCRkMkA). This video uses terminology and comparisons that will be familiar to your students, adding to their understanding of what a GMO is.
3. Display the GMO Crop Table (found on slide five of the *GMO* PowerPoint). Emphasize that the 10 crops listed in the first column are the only plants in our food supply with the potential of being genetically modified. The second column lists the trait that was "copied and pasted" into the genetic structure of these plants.
4. Next, teach what a GMO is not. Refer your students to their pile of food cards which have not currently been genetically modified. State that, "These foods have not been genetically modified, but they are different than their wild counterpart. They have changed through the years. How did this happen?" Draw on students' prior knowledge of science and genetics. Use guided questions to lead them to recognize that methods of natural and artificial selection have been used to improve our food crops for centuries. Review the following plant breeding techniques, using the information found in the *Background Agricultural Connections* section of the lesson to further define if needed:
	* Natural Selection
	* Artificial Selection
		+ Cross breeding/Hybridization
		+ Inbreeding
		+ Mutagenesis
5. Clearly explain that these traditional plant breeding processes have been used for many years to produce desired characteristics in plants. None of these processes use genetic engineering or genetic modification.
6. Summarize the difference between GM crops and crops created through traditional plant breeding by reviewing what students have recorded on the Venn Diagram found on page one of their handout. Check for understanding and help students fill in gaps as needed. An example can be found on slide seven of the *GMO* PowerPoint.

**Activity 2: Assessing the Risks and Benefits of GMO crops**

***What are the risks and benefits of genetically modified crops?***

1. Ask your students if they have ever seen news reports, memes, blogs, or other social media posts in strong opposition or support of GMOs. Hold a class discussion about some of the specific ideas and concerns students have or that they have heard from others. Summarize the discussion by concluding that it can be difficult to distinguish the facts (supported by credible evidence) from fiction (unsubstantiated opinions).
2. Conduct a Fact or Fiction class activity using either the attached PowerPoint or the Kahoot game linked below. As you conduct this activity, students should be taking notes on page two of their handout, *Critically Thinking GMOs*, by listing the benefits and risks of GMO crops.
	* **PowerPoint version:** Project the attached PowerPoint, *GMO Fact or Fiction?* Tell your students that you will be going through a list of claims regarding GM crops. Assign a signal to represent fact and a signal to represent fiction. (hold up a "fact" or "fiction" card, thumbs up for fact and thumbs down for fiction, etc.) Go through each slide individually. Project the claim and give students time to respond by giving the fact or fiction signal. Next, display the answer and the clarification. Discuss as needed.
	* **Kahoot version:** Access the ["GMO Fact or Fiction?"](https://play.kahoot.it/#/k/394a486d-74b4-45c2-9287-31ca90cd853a) Kahoot. Follow the basic Kahoot instructions or watch online tutorials for using this application in your classroom. Each student will need internet access through a tablet, smart phone, or computer to play the game. Explanations for each answer can be found in the PowerPoint version of the game.
		+ **Teacher tip:** You will find some additional explanation in the *Notes* portion of each PowerPoint slide. Hyperlinks are also included with several of the slides. You may also find more detailed answers on several subjects on the webpage [*Top 10 Consumer Questions About GMOs, Answered.*](https://gmoanswers.com/studies/top-10-consumer-questions-about-gmos-answered)
3. Using the information found in the *Background Agricultural Connections* section of the lesson, explain to your students some of the regulatory processes that must take place prior to the commercial use of GM crops.
4. After completing the fact or fiction activity, summarize and help students synthesize what they have learned. Refer again to the pile of "imposter" food cards and ask, "Why are so many foods at the grocery store labeled as "non-GMO" when that particular food product does not have a GMO counterpart?" *(Likely due to heightened fear, misinformation, and consumers' lack of understanding of what GMOs are. In response, food companies have begun labeling their products.)* As a follow-up question ask, "Do you think this labeling practice helps or hurts the food industry? Why?" *(Answers will vary)*

**Activity 3: How genetic engineering is used in the production of our food**

***How can genetic engineering address the supply (farm production) and demand (needs) of agricultural products?***

1. Refer to the instructions for the [*Have a Ball*](http://www.agclassroom.org/teacher/matrix/resources.cfm?rid=86&search_term_cr=have%20a%20ball) activity. As directed, use a ball with several numbers written on it to provide an object lesson about perspective and points of view. Help students understand that the use and implementation of biotechnology has many perspectives. Discuss how the point of view of a farmer, a scientist, and a consumer could have both differences and similarities. List these three people on the board and any others your students identify as having a different perspective.
2. Explain to your students that two factors determine the success of producing a crop. First, the farmer needs to be able to grow a safe product and produce an adequate harvest to be viable economically. Farmers provide our food supply. Second, consumers create the demand for a product when they purchase the product to meet their needs. The production of our food follows simple laws of supply and demand.
3. Use the following steps to draw a sketch on the board similar to the one below to illustrate:
	* Begin by writing the goal in the center of the board. Explain to your students that a successful crop satisfies the farmer and the consumer.
	* Next, draw two roads meeting together at the goal. Label one road for the farmer (supply) and the other road for the consumer (demand).
	* Last, explain that challenges will arise in meeting the ultimate goal. Illustrate the challenges by drawing a rock in each road. Explain that some challenges may be big and others may be small. Some challenges may stop the production or consumption of food altogether, and others may just slow it down.
4. Print the *Crop Supply and Demand Challenge Cards* and cut them in half. Distribute them to groups in your class. Ask each group to read the card and prepare to explain the challenge to their peers.
5. Have each student group present their challenge to the class. Determine if the challenge is faced by the farmer in order to produce a supply of food or if it is a "demand" from the consumer. Tape the card to the board on the appropriate side. Students should continue to make notes on page two of their *Critically Thinking GMOs* handout by continuing to list benefits and risks of GMOs.
	* **Optional:** After each student group presents a challenge, ask students to raise their hands and identify a perspective on that topic. Refer to the list of people you made in step 1 of this activity. Call on the students by tossing them the ball to present the perspective.
		+ For example, after discussing the "Pests" card a student may identify that a farmer's perspective would be to grow GM crops to eliminate a pest problem without the use of insecticides. Another student may identify that a consumer may choose food labeled as "organic " even if the cost is greater because of what they have read on social media about GMOs or chemicals used to control pests. Another student may point out that a different consumer would have no problem purchasing a GM crop, especially if it's cheaper.
6. Repeat step five until all the challenges have been presented and discussed.
	* **Teacher tip:** If time is short, speed this activity up by eliminating the student group participation outlined in steps 4-5. Instead, briefly introduce and describe the challenges to the students and place them on the board.
7. Summarize by reminding students that there are many methods and tools available to overcome these challenges. Methods available to farmers range from organic (without the use of chemicals) to conventional (using chemicals if necessary), and tools include the use of various traditional methods of selective breeding as well as the use of biotechnology to create GMOs.
8. Discuss the reality that although the science of genetic modification is sound, it still must be accepted by consumers to succeed. Consumers create the demand. For example, the development of Golden Rice was a scientific success but a social failure. Share the video, [*What is a GMO?*](https://youtu.be/Czx8nF7GrIM?t=2m16s) to illustrate. (The segment about Golden Rice begins at 2:15.) After watching the video ask the following questions:
	* What important nutrient did Golden Rice contain? *(beta carotene which the body converts into vitamin A)*
	* Why was Golden Rice rejected by the people it was designed to help? *(they feared it)*

**Concept Elaboration and Evaluation**

1. After conducting these activities students should recognize that the use of GM crops has scientific and social implications. Explain that socioscientific issues such as these are open-ended problems that may have multiple solutions. Evaluate student learning by following the instructions found on pages 3-4 of the *Critically Thinking GMOs* handout. Begin by dividing students into teams of two and assigning one student to be in favor of GMOs and the other to be against GMOs. Then have students follow the remaining instructions on the handout to complete the activity.
2. Review and summarize the following key concepts with your students:
	* Biotechnology is one tool that may help address challenges in food production (e.g., drought, pests, and disease) to meet the growing demand for food.
	* GM crops can increase crop yields (harvest) due to lower crop loss from pests, disease, and drought.
	* Although significant research is performed to evaluate the safety of GM crops for consumption as well as to assess the potential for harm to the environment, some consumers remain concerned by the social and economic issues related to increased use of biotechnology and GM crops.
	* The discussion on the safety of GM crops can be viewed from many perspectives (e.g., farmers, consumers, scientists, nutritionists).

**Enriching Activities**

* Display the [infographic](https://www.geneticliteracyproject.org/wp-content/uploads/2013/08/GLP-Science-and-GMOs.pdf) created by the Genetic Literacy Project.3 Allow students to read and discuss the statements made by science organizations throughout the world about the safety of consuming GM crops.
* As a formative assessment, assign students to find something in the news or on social media about GMOs and determine, based on scientific evidence, if the claim/opinion is accurate or not.
* Use the [Biotech Cheese Kit](http://www.agclassroom.org/teacher/matrix/resources.cfm?rid=36&search_term_cr=biotech%20cheese) to make cheese in your classroom. Your students may not know that most cheese is made using an enzyme developed through biotechnology. Historically, cheese was made using an enzyme called rennet which was obtained from the lining of a calf or other ruminant animal's stomach. Rennet is an enzyme which coagulates milk in the cheese making process. Biotechnology was used to develop [chymosin](https://en.wikipedia.org/wiki/Chymosin), which is now used widely in commercial cheese production.
* Orient students to the overall adoption and use of GM corn, cotton, and soybeans by visiting the USDA Economic Research Service webpage.1 Project their chart titled, [*Adoption of genetically engineered crops in the United States, 1996-2015.*](http://www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us/recent-trends-in-ge-adoption.aspx)Help orient the students to the graph by explaining that it represents the adoption and use of GMO corn, cotton, and soybeans in the United States since in 1996. Explain that "HT" stands for herbicide tolerance and "Bt" stands for *Bacillus thuringiensis* which is an insect resistant crop. Ask students, "What is the general trend for the adoption and use of GM corn, cotton, and soybeans?" *(generally increasing with some years/crops showing a small dip)*
* As a homework assignment, have students visit the *GMO Answers* website and browse through the [Featured Questions](https://gmoanswers.com/ask) page. This website is designed for consumers to ask questions about GMOs. Assign students to find two questions or topics that interest them and then write a response to each question in their own words using what they learn through the given responses and linked articles.
* Use the attached *GMO Crop Spotlight* sheets to assign individual students or groups of students to research the current GM crops available on the market. The [ISAAA](http://www.isaaa.org/gmapprovaldatabase/) website contains a crop database with pertinent information for students to complete the assignment successfully.

**Suggested Companion Resources**

* [GMO Case Study](http://www.agclassroom.org/teacher/matrix/resources.cfm?rid=262) (Activity)
* [Biotech Cheese Kit](http://www.agclassroom.org/teacher/matrix/resources.cfm?rid=36) (Kit)
* [Crop Modification Techniques](http://www.agclassroom.org/teacher/matrix/resources.cfm?rid=768) (Poster, Map, Infographic)
* [Crop Genetic Engineering Simulation](http://www.agclassroom.org/teacher/matrix/resources.cfm?rid=581) (Multimedia)
* [Genetically Engineered Crops Report](http://www.agclassroom.org/teacher/matrix/resources.cfm?rid=648) (Multimedia)
* [Genetically Engineered Crops in the United States Report](http://www.agclassroom.org/teacher/matrix/resources.cfm?rid=752) (Multimedia)
* [Genetically Modified Food: Good, Bad, Ugly](http://www.agclassroom.org/teacher/matrix/resources.cfm?rid=503) (Multimedia)
* [Give it a Minute: Organic & Conventional Farming](http://www.agclassroom.org/teacher/matrix/resources.cfm?rid=463) (Multimedia)
* [How Are GMOs Created?](http://www.agclassroom.org/teacher/matrix/resources.cfm?rid=592) (Multimedia)
* [NASA Shows U.S. Corn Belt Literally Glowing with Productivity](http://www.agclassroom.org/teacher/matrix/resources.cfm?rid=497) (Multimedia)
* [Natural GMO? Sweet Potato Genetically Modified 8,000 Years Ago](http://www.agclassroom.org/teacher/matrix/resources.cfm?rid=589) (Multimedia)
* [Why are GMOs Bad?](http://www.agclassroom.org/teacher/matrix/resources.cfm?rid=461) (Multimedia)
* [Biotech in Focus](http://www.agclassroom.org/teacher/matrix/resources.cfm?rid=489) (Booklets & Readers)
* [Food Dialogues](http://www.agclassroom.org/teacher/matrix/resources.cfm?rid=523) (Website)
* [GMO Answers](http://www.agclassroom.org/teacher/matrix/resources.cfm?rid=244) (Website)
* [Genetic Science Learning Center](http://www.agclassroom.org/teacher/matrix/resources.cfm?rid=255) (Website)
* [Journey of a Gene](http://www.agclassroom.org/teacher/matrix/resources.cfm?rid=474) (Website)
* [What's In My Food?](http://www.agclassroom.org/teacher/matrix/resources.cfm?rid=652) (Website)

**Sources/Credits**

Ann Butkowski, science teacher at Humbolt High School in St. Paul, MN wrote the original lesson for the Minnesota Agriculture in the Classroom program in 2013. The lesson was rewritten and updated in 2016 by National Agriculture in the Classroom.

The *Critically Thinking GMOs* worksheet was developed using the concepts taught in the NSTA publication of [Making Critical Friends](https://www.nsta.org/store/product_detail.aspx?id=10.2505/4/tst16_083_02_23), written by Sara Raven, Vanessa Klein, and Bahadir Namdar.

1. <http://www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us/recent-trends-in-ge-adoption.aspx>
2. <http://sitn.hms.harvard.edu/flash/2015/gmos-and-pesticides/>
3. <https://www.geneticliteracyproject.org/2013/08/27/glp-infographic-international-science-organizations-on-crop-biotechnology-safety/#.UlQecCRJNOE>
4. <http://www.foodnavigator-usa.com/Manufacturers/87-of-consumers-globally-think-non-GMO-is-healthier>
5. <http://www.hindawi.com/journals/ijpg/2011/314829/>
6. <http://www.fao.org/docrep/006/y4955e/y4955e03.htm>
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12. <http://www.ecowatch.com/organic-food-industry-explodes-as-consumer-demand-spikes-1882033908.html>
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