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| **Title** | Improved or Engineered? A Look at the Processes involved with High Tech and Low Tech Genetic Modifications |
| **Introduction** | Often, students hear the term ‘genetically modified’ and assume that this is a new process, most of which is created in a lab. Most students do not realize that forms of genetic modification have been around for centuries. In this lesson, students will explore the processes of genetic engineering [high tech] vs. genetic improvement [low tech], and learn to distinguish between the processes. They will examine benefits and drawbacks of each process by storyboarding and visually representing the process to see similarities as well as differences in the processes. Following the activity, students will compare and contrast processes, or as an extension may research one specific type of tree and discuss/report on the processes used in its modification. |
| **Curriculum Alignment** | AP Environmental Science-  Competency Goal 7: The learner will build an understanding of environmental decision making.  Objective 7.02 Analyze cultural and ethical considerations regarding the environment; Environmental worldviews; Sustainable development.  Biology NC Essential Standards  Bio.3.3.3- Evaluate some of the ethical issues surrounding the use of DNA technology (including cloning, genetically modified organisms, stem cell research, and Human Genome Project). |
| **Learning Outcomes** | During the Activity:  Students must use prior knowledge and knowledge of sequencing to determine placement of individual steps within the sequence of genetic engineering or genetic improvement. Students will create visual representations of the processes involved in both types of genetic modification and will use their own knowledge to place the steps in order, as well as be able to present the entire process from beginning to end.  End of Activity:  Students will look at the two different processes and seek similarities [such as end product, purpose of modification] with contrasts [method of genetic alteration, time involved, costs] of the two types of processes. An understanding of how each process works is necessary to be able to accurately compare and contrast the processes. Understanding is shown by completing the comparison assessment, as well as the opportunity to assess for any misconceptions. [The act of putting the information in writing forces students to ‘find the right words’ which they might not be able to do just listening to discussion and thinking to themselves]. |
| **Time Required and Location** | Introductions and brainstorming session [with time to work in groups and put ideas on board]- 10 minutes  Go over brainstormed ideas and correct misconceptions- 10 minutes  Create posters for storyboarded processes- 15 minutes  Place in order within large groups and go over processes- 15 minutes  Time to compare processes and complete handout- 10 minutes  TOTAL TIME: 60 minutes |
| **Materials Needed** | * Posterboard or bulletin board/ art paper for visual images   + To save space, 8.5 x 11” computer paper can be used.     - Two different light colored sheets can help distinguish the different processes * Markers/ crayons * Construction paper [optional] * Glue * Other art supplies   + Option- provide students with posterboard, and crayons/markers. Anything else they choose to add can be bought in by their group from home. * Tape- to hang on wall * Copies of compare/ contrast handout [may project using projector and have students use own paper]   Internet access and computers may be used for research extension- but can also be utilized outside of class for those students interested. |
| **Participant Prior Knowledge** | At this point, students should have a basic understanding of what genetic modification is- as well as some ways that it can be accomplished. Students should also have a basic understanding of genetics and how crossbreeding can lead to genetic changes.  This activity is designed for high school students, so these students should have a clear concept of sequencing. If adapted for younger students, a review of sequencing may be needed, and terminology may need to be simplified slightly. |
| **Facilitator Preparations** | Teachers should have already made copies of the compare/ contrast handouts for the assessment, as well as printed and cut the sequence strips that outline the processes.  Teacher should be familiar with steps involved in the processes of genetically engineering and genetically improving plants. Its important to use these terms as separate terms early in discussion of GM technology, so that students are aware of the differences.  Genetic Engineering involves the use of genes inserted into the genomes of organisms. It’s specific, quicker, and comes with ethical issues.  Genetic Improvement is the ‘low tech’ version of this and is a much older process, that utilizes crossbreeding and selective breeding to make sure that the organisms produces the desired results. Much more possibility for error or smaller gains, and takes longer, but this is a much more accepted management practice with few ethical issues.  Tip- Print ‘genetically engineered’ and ‘genetically improved’ statements on different colors of paper. This makes it easier to visually distinguish working groups immediately. |
| **Activities** | **Exploration:**   1. Ask students to brainstorm for 3 minutes [time can be adjusted, but should be brief] to write down anything that come to mind when they think of the processes used in creating ‘genetically modified’ trees. 2. Have students work within small groups [if classroom layout easily allows for this] to see how their answers compared to their peers. 3. Ask students to create two columns on a piece of paper and list each process /idea/statement into one of two columns: requires technology vs. does not require technology 4. While they are doing this, create two columns [same headings] on the board. 5. Ask each group to come up to the board and list at least 2 unique things in each column. 6. Discuss each of the statements listed with the class.    1. Misconception correction point- this is a great time to correct any clear initial misconceptions with students. Typical misconceptions are:       1. All genetic modification involves technology       2. It’s a new process [think: crossbreeding of plants, centuries old process] Mendel was onto something! ☺       3. The process is quick and can be done in just a few months or years.   **Model System:**  Place students into small groups. 10 groups are needed for this activity. If you have a small class, you may have each group complete one step in each process and combine groups accordingly.   1. Hand each student a strip of paper containing a sentence or step.    1. Students must look at their step, figure out at what point in the process they think their step falls, and create a way to visually represent their step within the process.    2. Students will brainstorm and write ideas and sketch possible visual examples on their own to try to find a way to present their concept without actually stating the step.    3. Students may elect to do some research [if the option is available in the classroom for them to do any outside research- use of smartphones with Acceptable Use Contract and administrative approval, computer desktop for research, mobile laptop lab, personal laptops if the school allows them].    4. Students will visually create their ‘step’ without using words to explain the step.       1. Write the step on the back of the paper/poster.   **Content Wrap-Up:**   1. Students from each of the five steps should meet and look over their individual steps and determine the overall order. Tape posters/papers on opposing walls in the classroom [for the different processes] in order. Discuss the process as a group and determine how to present the process as a whole to the rest of the class.    1. If you have condensed this down to 5 groups total, the smaller class may do one process as a time and do this as a whole group- or the groups will split and send at least one person to each side for each step. 2. At this point, make sure students understand the content related to their process. If you have a biotechnology section or chapter in your textbook, have students reference this, and utilize it in figuring out their process more in depth.    1. Check for content understanding by seeing that all steps are in order and that each person in the group can help in the explanation of what happens going from one step to the next. This is especially difficult to do for larger classes as sometimes students will ‘sink into the background.’       1. Option- do not let students decide who will be speaking for them to present the information. Randomly select students [draw cards, draw straws, random number generator based on alphabetical order or another factor] to be the ones to present. Only allow presenting students to use materials that they have written down themselves [which will help make sure that more students are taking notes and writing down information]. 3. The answer key for the processes in order is found on the handout with the processes listed. They’re already in order. ☺ This can also serve as a ‘heading’ to place to the left of the papers/posters as they are placed on the walls in the room.   **Guided Practice**  Students will look at the processes and discuss to the other side of the class how the process works. Connect to what the students already know about processes of biotechnology and genetic modifications. As a class, discuss these process and how they might differ, taking into consideration topics such as:   * Length of time involved in the process- genetic improvement takes longer and will get less significant results * Potential issues that result- allergens being introduced, unknown long term effects   If students show any misconceptions, be sure to correct them as you facilitate discussion as needed. |
| **Activities** | **Exploration:**   1. Ask students to brainstorm for 3 minutes [time can be adjusted, but should be brief] to write down anything that come to mind when they think of the processes used in creating ‘genetically modified’ trees. 2. Have students work within small groups [if classroom layout easily allows for this] to see how their answers compared to their peers. 3. Ask students to create two columns on a piece of paper and list each process /idea/statement into one of two columns: requires technology vs. does not require technology 4. While they are doing this, create two columns [same headings] on the board. 5. Ask each group to come up to the board and list at least 2 unique things in each column. 6. Discuss each of the statements listed with the class.    1. Misconception correction point- this is a great time to correct any clear initial misconceptions with students. Typical misconceptions are:       1. All genetic modification involves technology       2. It’s a new process [think: crossbreeding of plants, centuries old process] Mendel was onto something! ☺       3. The process is quick and can be done in just a few months or years.   **Model System:**  Place students into small groups. 10 groups are needed for this activity. If you have a small class, you may have each group complete one step in each process and combine groups accordingly.   1. Hand each student a strip of paper containing a sentence or step.    1. Students must look at their step, figure out at what point in the process they think their step falls, and create a way to visually represent their step within the process.    2. Students will brainstorm and write ideas and sketch possible visual examples on their own to try to find a way to present their concept without actually stating the step.    3. Students may elect to do some research [if the option is available in the classroom for them to do any outside research- use of smartphones with Acceptable Use Contract and administrative approval, computer desktop for research, mobile laptop lab, personal laptops if the school allows them].    4. Students will visually create their ‘step’ without using words to explain the step.       1. Write the step on the back of the paper/poster.   **Content Wrap-Up:**   1. Students from each of the five steps should meet and look over their individual steps and determine the overall order. Tape posters/papers on opposing walls in the classroom [for the different processes] in order. Discuss the process as a group and determine how to present the process as a whole to the rest of the class.    1. If you have condensed this down to 5 groups total, the smaller class may do one process as a time and do this as a whole group- or the groups will split and send at least one person to each side for each step. 2. At this point, make sure students understand the content related to their process. If you have a biotechnology section or chapter in your textbook, have students reference this, and utilize it in figuring out their process more in depth.    1. Check for content understanding by seeing that all steps are in order and that each person in the group can help in the explanation of what happens going from one step to the next. This is especially difficult to do for larger classes as sometimes students will ‘sink into the background.’       1. Option- do not let students decide who will be speaking for them to present the information. Randomly select students [draw cards, draw straws, random number generator based on alphabetical order or another factor] to be the ones to present. Only allow presenting students to use materials that they have written down themselves [which will help make sure that more students are taking notes and writing down information]. 3. The answer key for the processes in order is found on the handout with the processes listed. They’re already in order. ☺ This can also serve as a ‘heading’ to place to the left of the papers/posters as they are placed on the walls in the room.   **Guided Practice**  Students will look at the processes and discuss to the other side of the class how the process works. Connect to what the students already know about processes of biotechnology and genetic modifications. As a class, discuss these process and how they might differ, taking into consideration topics such as:   * Length of time involved in the process- genetic improvement takes longer and will get less significant results * Potential issues that result- allergens being introduced, unknown long term effects   If students show any misconceptions, be sure to correct them as you facilitate discussion as needed. |
| **Assessment** | Hand students the “Comparing and Contrasting Processes” handout. Give them the opportunity to utilize their book and notes, as well as walk around the class to observe the different steps involved in the contrasted processes, to fill out the table.  [if copies are limited at your school, this may be projected onto a screen and copied by students onto their own paper; this can also be printed two pages per sheet to save paper]  To check this, look for completed papers and look for the explanations for which method the student feels is more beneficial in the long term. Look that students are able to use and apply the information in the chart to form a conclusion and support it. |
| **Critical Vocabulary** | Forestry Dictionary- Maryland Dept. of Natural Resources- <http://www.dnr.state.md.us/forests/gloss.html>  Genetic improvement- use of crossbreeding and natural practices to increase crop yields  Genetic engineering- use of inserted genes to create genetically different plants; modified for a specific purpose  Plasmid- how a new gene is inserted into a genome of the receiving plant |
| **Modifications** | Modification for EC/ ESL students:   * Before storyboarding the entire process, students can use the sentence strips to place the steps in order and paste them onto one sheet. This helps students to see where their step fits into the overall process and can help provide some added structure to the lesson for these students.   Modifications for gifted students:   * As an extension, students may select one tree type that has been either engineered or improved and follow the process to determine why it has been completed as it has been. Why choose one process over the other? This research can be conducted either in small groups in class using shared computers or outside of class. An alternative assessment is listed below.   Use the website listed for **Steps for Creating a GMO** for great modifications for visual learners or lower level students. These include both animations to follow the steps, as well as an interactive game that outlines variations in the process. |
| **Alternative Assessments** | ESL students may be given the sentence strips as an assessment on the following day. This can allow them to use context clue within the structure of the statements to help them place in the correct order and help build English language skills.  Diverse classrooms- in classrooms with many EC students, students may complete the compare/contrast handout in pairs or teams.  Gifted students- Students can complete a short report on the process involved with one specific tree. An alternate would be that these students could use this research and then come back as a class to discuss the pros and cons of each process using specific examples. Assessment in this case would be via oral cues.   * What to look for in oral assessment: students should be able to convey that the trees that are being genetically engineered are resulting in more complex and extreme changes, such as pest resistance [American chestnut], increased pulp production from lignin content alteration [cottonwood, pine], and increased range of climate tolerance [eucalyptus]. Trees that are being genetically improved are taking longer to see results and the results are usually more natural in appearance, such as faster growth, taller trees, increased natural pest resistance, etc. Usually these are done to species that are native to the local area in which the improvement is occurring. |
| **References** | See Supplemental Information for a list of news outlets that would be helpful.  [www.ncus.ecu](http://www.ncus.ecu) – NC State University  lots of great available links within the Dept of Forestry and Natural Resources  [www.ncforestsevice.gov-](http://www.ncforestsevice.gov-) NC forest service – some Claridge information is available online  example of location that uses genetic modification  [www.arborgen.com-](http://www.arborgen.com-) ArborGen website  example of company that uses genetic engineering  **Steps for Creating a GMO**  *http://cropwatch.unl.edu/web/biotechnology/makinggmo*  This site contains the steps used for the “Genetically Engineered” process. The steps are included, as are images and animations of each process. [great modification for visual learner students to review]  This site also contains a great game entitled “Who wants to be a genetic engineer?” which would serve as a great review of the processes where time and technology allow.  **The Tree Improvement Process [by John Frampton]**  *http://www4.ncsu.edu/~frampton/additional%20reading/tree.htm*  This website follows the process of genetic improvement, and also has graphical representations. |
| **Supplemental Information** | This topic is extremely varied and most of the up to date information will change rapidly. The best way to find current research and data is to check news sites, such as:  CNN  Environmental News Network  Forest Ethics  American Forest Foundation  Online scientific journals  NC Forest Service is a great tool to use. [www.ncforestservice.org](http://www.ncforestservice.org).   * Claridge Nursery in Goldsboro, NC is a great location to visit or research; they use genetic improvement of their trees.   ArborGen is a company in Summerville, SC that is doing some great cutting edge research with genetic engineering.  NCSU also has many great professors and researchers in the areas of forestry and forest biotechnology. If you are in the Raleigh area, you may be able to get a guest speaker to come to your school and discuss their research. [possibly a professor or a graduate student] |
| **Comments** | There are a lot of directions this lesson can take depending on your class population.  Examples-  Large number of ESL students or EC students   * Start off with cut strips for each student and have them place in order. * Have students review process; follow with storyboarding. * Have students work in groups to complete worksheet. * [next day] have students place steps in order as a quiz grade   Honors Class   * Start with groups, each student has a single strip. Make all strips the same color so that students have to group themselves based on which process they think they have. * Work to create storyboard visuals. * Present to class. * Complete handout individually. * Work in groups or individuals to find a type of tree that has been improved or engineered and use that information to discuss the processes as a class. [allow up to one week for research] * As written, this allows for a lot of condensation based on time constraints. If you have even less time, students can be given the strips, have to put them in order, and then have them draw all of the steps out on their own. This would work well in a class where time is very limited, such as a block semester biology course. |

Making a Genetically Engineered Crop

 In general there are five different steps required for using biotechnology to creates a new crop variety.  These same steps are used no matter what the crop is.  We will use the example of BT corn for describing each of these five steps.  The soil bacterium, Bacillius thiurengensis, produces an insecticidal protein.  That protein is coded for by a certain gene, one example is cry 1Ab.

All of the DNA from Bacillius thiurengensis, is isolated in a laboratory.

In the laboratory the specific DNA sequence which makes up the cry 1Ab gene is found and copied.

The cry 1Ab soil bacterium version of the gene is modified slightly so that it will work better once in a corn plant.

In a laboratory a corn plant is transformed with this new modified cry 1Ab gene which will provide the corn plant with insecticidal protection.

Plant breeders cross this corn plant (which contains the cry 1Ab gene) with their top performing lines to create a high yielding BT corn variety.

Tree Improvement

Trees are selected from unimproved natural stands and plantations that contain desired traits.

Unimproved trees are crossbred to produce more genetically desirable traits.

Trees are grown together in seed orchards until they begin to produce pollen.

Pollen is collected and crossbred with other higher yield plants to increase yield, and seedlings are planted to grow.

The seed and pollen producing tops of younger plants are grafted onto mature trees to speed up process of improvement, and resulting in trees containing the desired traits.

**Genetic Improvement vs. Genetic Engineering**

**Comparing and Contrasting Processes**

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| --- | --- | --- | --- |
|  | **Improvement only** | **Both Improvement and Engineering** | **Engineering only** |
| *Time required* |  |  |  |
| *Results of process* |  |  |  |
| *Ethical issues to consider* |  |  |  |

***Which process do you think is more beneficial in the long term? Explain.***