KPS 4 Parents
Knowledge Powers Solutions for Parents

Grade Level: Eighth
Piagetian Level: Early Formal

Learners with the earliest aspects of formal operations intact and more sophisticated formal operations emerging are suited for this activity.

STEM *Science, Technology, Engineering, & Mathematics*

Learn & Grow Educational Series℠

Genetic Trait Variation in String Beans

Instructional Goals: Following instruction and participation, students will explain the natural processes of genetic trait dominance, additive and epistatic genes, single-locus traits, and quantitative trait loci; students will further relate these processes to variations in green beans with respect to pod traits such as size and color.

Lines of Inquiry:

- *What are the natural processes of the expression of genetic traits in beans?*
- *Why is it important to understand how genetic traits are naturally expressed in food-bearing plants?*
- *How does deliberate cross-breeding of bean varieties create new varieties with specific traits?*
- *Why is it important to study the effects of deliberately cross-breeding different varieties of food-bearing plants?*

Materials:

Assignment 1 -

- *Research & reference tools & materials*
- *Tools & materials to produce the assigned work product, whether it is a written report, PowerPoint® presentation, video, poster, or some other method of demonstrating mastery of the instructed concepts*

Assignment 2 -

- *Tools & materials for building out one self-watering container per student. (See http://learn-and-grow.org for instructions & materials)*
- *Organic potting soil with compost or fertilizer mixed into it—enough for each container*
- *3 purple bean seeds per student*
- *3 green bean seeds per student*
- *3 yellow bean seeds per student*
- *Water for each self-watering container's reservoir*
- *9 plant markers/flags per student*
- *Data sheets, pens/pencils, writing surface*

Common Core Standards:

- RST-6-8.1. Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
- RST-6-8.9. Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.
- WHST.6-8.2. Write informative/ explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.
- WHST.6-8.9. Draw evidence from informational texts to support analysis, reflection, and research.
- SL.8.1. Engage effectively in a range of collaborative discussions (one-on-one, in groups, teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.
- SL.8.4. Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.
- 6.RP.A.1. Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities.
- 6.SP.B.5. Summarize numerical data sets in relation to their context.
- 7.RP.A.2. Recognize and represent proportional relationships between quantities.

CA State Standards—Science:

- MS-LS4-4. Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.

Genetic Trait Variation in String Beans, continued...

<u>*Instructions:*</u>

Assignment 1 -

1. *Have your students research Mendel's experiment with peas and produce work product according to your instructions, including a Punnett Square diagramming their findings regarding trait dominance in peas.*

2. *Discuss with the class the 3:1 ratio of dominant versus recessive trait expression per Mendel's experiment.*

3. *Have your students discuss as a group the traits of string beans, namely pod and seed qualities such as size and color.*

Assignment 2 -

Start by having students read the following passage in their hand-outs:

This reading passage summarizes data and its interpretations from the peer-reviewed research article "Genetic variation underlying pod size and color traits of common bean depends on quantitative trait loci with epistatic effects," which appeared in the April 2014 issue of the professional scientific journal *Molecular Breeding.* This journal article was authored by researchers in Spain, namely Fernando J. Yuste-Lisbona, Ana M. González, Carmen Capel, manuel García-Alcázar, Juan Capel, Antonio M. De Ron, Marta Santalla, and Rafael Lozano.

According to these researchers: "Common bean is an important vegetable legume in many regions of the world. Size and color of fresh pods are the key factors for deciding the commercial acceptance of bean as a fresh vegetable. The genetic basis of important horticultural traits of common bean is still poorly understood, which hinders DNA marker-assisted breeding in this crop."

Think about what this means, for a moment. Beans are grown all over the world. *Almost everybody* eats beans in one form or another. We eat shelled beans (bean seeds removed from their pods) by cooking them in soups, making chili out of them, or just boiling them in water with spices and eating them with cooked rice.

We eat beans in their pods as string beans, which come in a variety of colors, including purple, green, and yellow. When people shop for fresh string beans, they look at the color, length, thickness, stringiness, stage of development, and freshness of the beans. Different varieties of string beans have subtly different flavors with some being more sweet and others being more savory.

If string beans are *too* stringy, they are unpleasant to chew, so this pod characteristic is something that shoppers also judge as they are buying fresh string beans. In order to make some varieties more pleasant to chew, their stems and beaks are snapped off with the strings along the seams of the pod still attached, then pulled like a zipper down the length of the pod and completely off. Sometimes, both sides of the pod need to have strings removed before they are pleasant to chew.

Other pods are covered with a light fuzz that can't be removed that some people find unpleasant to chew. String beans with smooth pods that are not too stringy are preferred by buyers, particularly those buying beans to feed small children and people with dental problems, so it is important for farmers to grow the kinds of beans that satisfy buyers' preferences and make them edible for people who cannot chew tougher, stringier, and/or fuzzier beans.

This makes the researchers' statement that "[t]he genetic basis of important horticultural traits of common bean is still poorly understood, which hinders DNA marker-assisted breeding in this crop," really mean something. It basically states that scientists really haven't had a good understanding of the genetic factors responsible for all the things about string beans that make people want to buy them. All of the qualities of the pods – their color, texture, stringiness, length, etc. - are things that need to be identified according to the genetics involved, which is what this research article goes on to explore.

In the end, the researchers determined through their experiments that pod size and color traits of common bean depend on "*quantitative trait loci with epistatic effects*." So, what does that mean?

Quantitative traits are characteristics of the bean plant that can be *measured*, such as pod length, seed size, stem thickness, leaf color, etc. Color is considered a measurable trait because it is the result of the interactions of light with surfaces that have varying and, therefore, measurable, degrees of light absorbing and reflecting capacities. Light, itself, comes with its own measurable qualities.

Genetic Trait Variation in String Beans, continued…

We already know that light plays a very important role in plant survival and growth as plants capture the energy of light and convert it to food energy at the very beginning of the food chain through photosynthesis. Clearly, plant color is an important genetic trait for many reasons, other than just the appearance of bean pods to potential human buyers.

Understanding the quantitative traits of green beans helps us grow important crop vegetables that people will want to eat. Another important consideration other than consumer preference, however, is consumer *health*.

Food is meant to nourish the human body, not simply entertain it with delightful smells and tastes. Food is fuel. Without it, we die. The only reason foods taste good or bad to us is because we evolved these senses thousands of years ago in the wild to prevent ourselves from eating rancid meat and poisonous plants while scavenging off the land as primitives; it was an evolutionary mechanism to promote the survival of the human species.

Our circumstances have changed, now, but our bodies are still wired to our brains in a way that causes us to prefer food for its pleasurable qualities rather than necessarily its nutritional ones. Salts, sugars, and fats – things difficult to come by in the wild – are now easily attainable and our strong preferences for these substances lead many people to become addicted to foods heavy in salts, fats, and sugars.

In the wild, we crave these things to ensure that we eat them when we can. In a grocery store or restaurant, these cravings can encourage us to eat more than is healthy because our environment no longer restricts our access to these things like it did thousands of years ago when humans lived in the wild.

Fast food restaurants, frozen dinners, and pastry shops exist because of this phenomenon. It has also led to a worldwide epidemic of morbid obesity and diabetes. Diet-related health disorders kill many, many more people in America than guns. In fact, diet-related health disorders are the biggest killers in America, causing more deaths than anything else in the country.

When people's bodies get too big for their organs to work properly, their health quickly declines. Diabetes can cause people to lose their eyesight as well as their feet and/or legs.

Poor health makes it harder for people to exercise to make themselves healthier and the whole situation becomes a vicious cycle. It can be very difficult to lose excess weight once a person has gained it. If obesity and/or diabetes become advanced enough, they can each lead to death.

When people lived in the wild, plants were far easier to come by than animals to eat. Humans largely lived on plant diets, adding animal protein when we were able to do so, which was usually not often. Being able to get by on many different types of plants ensured our survival as a species.

Humans evolved in symbiosis with our environments to develop the abilities to digest and take nutrition from all kinds of plants. The plants that found it beneficial to supply us with food evolved to suit our liking in order to encourage us to eat them.

Food is fuel.
Without it, we die.

For this reason, these plants are now loaded with nutrients that our bodies need. Diets that are almost exclusively made up of fats, salts, and sugars will not supply these nutrients. We have to eat plants in order to be healthy, which means that we cannot breed our crop vegetables to simply be pretty, tasty, and pleasant to chew; they also have to maintain the nutritional values they exist to provide to us.

These plants exist to give us the nutrients we can't get from foods loaded with fats, sugars, and salts. If we breed out the genetic traits that make these plants healthy for us, they can't do their jobs for us to keep us alive and healthy.

Our bodies are biochemical machines that require substances that they cannot create for themselves, which means we must take these substances from the environment. If we don't put the right chemicals into our bodies, our bodies can't operate the ways they were designed to operate. It's like pouring diesel fuel into a gasoline engine – the wrong fuel will prevent the engine from operating properly and the engine will break down and fail. In human beings, "engine failure" means serious illness and death.

Breeding for crop vegetables means satisfying a lot of demands, not the least of which is public health. As such, identifying the genetic markers for bean traits is pretty important to growing the kinds of beans that will both nourish people and be pleasant for them to eat.

Quantitative trait loci, as referenced in the article, are stretches of DNA containing or linking to genes that underlie a quantitative trait (such as pod length). The term "loci" refers to locations along the DNA strand; a single location is a locus where multiple locations are loci. So, quantitative trait loci in this case are the places along a bean's DNA strand that *together* interact in a

Genetic Trait Variation in String Beans, continued...

way that controls for quantitative traits such as seed size, pod color, pod thickness, etc.

A **single-locus trait** is a genetic trait that is the result of the genes located at a single point along a strand of DNA. There are no interactions with other genes at other loci that make the trait occur. This is what happens in gene dominance where the interaction is limited to being between the two parent genes and none of the other genes along the strand of DNA.

Look back to Assignment 1 where you studied Mendel's pea experiments and created your Punnet Square. This was an experiment that revealed the effects of a single-locus trait because only one gene pairing between parent DNA was involved and no other genes.

By comparison, genes at the quantitative trait loci are connected among each other along strands of DNA to interact in order for a trait to be produced, as well as control for how that trait manifests. In many instances, the combination of gene qualities at the various trait loci must be exactly right in order for the trait to show up at all. It's kind of like a combination lock, where only the right combination of numbers at the right positions will open the lock.

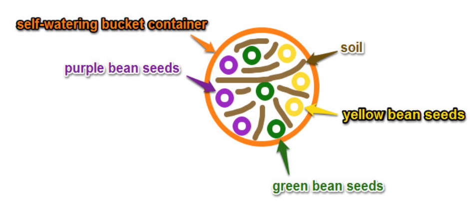
There are two ways that the genes at the quantitative trait loci interact with each other. They are either additive or epistatic.

Additive genes occur when more than one gene is present that codes for the same trait. Rather than one gene canceling the other one out, as with dominance, they combine in a unique way to create something new. This can occur with a single-locus trait or a trait with multiple trait loci.

Epistatic genes only express themselves if other genes are also present. Again, this can happen with either a single-locus trait or a trait with multiple loci. When an epistatic relationship among genes occurs involving multiple trait loci, you get the "combination lock effect" discussed above. When this happens, we say that the traits depend on loci with epistatic effects.

The research on beans conducted by the authors discussed above concluded that this very "combination lock effect" is responsible for the pod size and color traits in common beans. As the title of the article states: "Genetic variation underlying **pod size** and **color traits** of **common bean** depends on **quantitative trait loci with epistatic effects**." [Emphasis added.]

1. *Have your students build out a self-watering container garden (see http://learn-and-grow.org for instructions and a materials list), building one self-watering container per student. Each student will care for the same container for the remainder of this experiment.*
2. *Have your students fill the upper chambers of their containers with soil and the reservoirs with water.*
3. *Give each student three each of purple, green, and yellow bean seeds.*
4. *Have each student record in his/her data sheet his/her observations about each type of bean seeds.*
5. *Have each student plant his/her bean seeds approximately one inch deep in his/her container's soil more or less as indicated in the diagram below. Have students mark each of their plants with a marker/flag as indicated on page 5 of the Student Instruction & Data Sheets.*



6. *After 2 days, have the students begin checking their plants daily to see when they sprout.*
7. *Once the seedlings appear, have students take data weekly on the appearance of the plants over the next twelve weeks. You may opt to have students take photos of their plants at each data point as part of their data collection and record keeping.*
8. *On their data collection and reporting sheets, have your students summarize their individual understandings of trait dominance, additive genes, epistatic genes, single-locus traits, quantitative traits, and multiple trait loci.*
9. *On their data collection and reporting sheets, have your students summarize their analyses of the physical qualities of the three different bean plants they've grown and how their pod traits relate to trait dominance, additive and epistatic genes, single-locus traits, and quantitative trait loci.*
10. *Grow the plants to harvest and see if any cross-pollination occurred. If so, have your students discuss natural selection as it has occurred in their bean garden with three different varieties of beans being grown together. If not, discuss what may have prevented cross-pollination from occurring among the bean varieties.*

Where possible, children should be encouraged to eat the fruits and vegetables they grow in order to make the cognitive connections between growing food, where food comes from, how food provides fuel to the human body, and how healthy foods make a difference in how the mind and body feel and work. This also gives them a sense of empowerment and control over their

Genetic Trait Variation in String Beans- Assignment 1 & 2 Student Instruction & Data Sheet

Name: ________________________________

Introduction:

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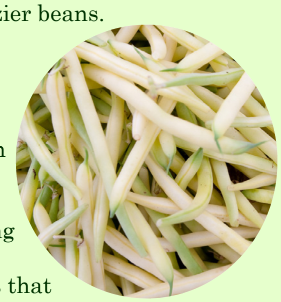

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Genetic Trait Variation in String Beans-
Assignment 1 & 2 Student Instruction & Data Sheet

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A **single-locus trait** is a genetic trait that is the result of the genes located at a single point along a strand of DNA. There are no interactions with other genes at other loci that make the trait occur. This is what happens in gene dominance where the interaction is limited to being between the two parent genes and none of the other genes along the strand of DNA.

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Genetic Trait Variation in String Beans-
Assignment 1 & 2 Student Instruction & Data Sheet

Materials:

Assignment 1 -

- Research & reference tools & materials
- Tools & materials to produce the assigned work product, whether it is a written report, PowerPoint® presentation, video, poster, or some other method of demonstrating mastery of the instructed concepts

Assignment 2 -

- Tools & materials for building out one self-watering container (see http://learn-and-grow.org for instructions & materials)
- Organic potting soil with compost or fertilizer mixed into it for your self-watering bucket container
- 3 each of purple, yellow, and green bean seeds
- Water for your self-watering container's reservoir
- 9 plant markers/flags
- Data sheets, pens/pencils, writing surface

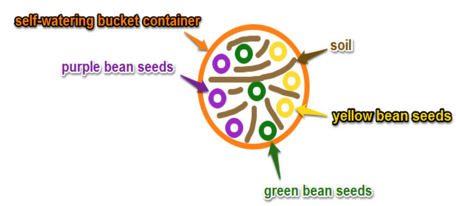
Instructions:

Assignment 1 -

1. Following your teacher's instruction, research Mendel's experiment with peas and produce work product according to your instructions, to include a Punnett Square diagramming their findings regarding trait dominance in peas.
2. Under your teacher's guidance, discuss with your class the 3:1 ratio of dominant versus recessive trait expression per Mendel's experiment.
3. Under your teacher's guidance, discuss with your class the traits of green beans, namely pod width, thickness, length, size index, beak length, and color.

Assignment 2 -

1. Under your teacher's guidance, build out a self-watering container (see http://learn-and-grow.org for instructions and a materials list) for yourself. You will care for this same container for the remainder of this experiment.
2. Fill the upper chamber of your container with soil and the reservoir with water.
3. Get from your teacher three each of purple, green, and yellow bean seeds.
4. Record on your data sheet your observations about each type of bean seeds.
5. Plant your bean seeds approximately one inch deep in your container's soil more or less as indicated in the diagram below. Mark each plant with a marker/flag as indicated on page 5 in the chart on the right side of the page.



6. After 2 days, begin checking your plants daily to see when they sprout and monitor their growth.
7. Once the seedlings appear, take data weekly on the appearance of your plants over the next twelve weeks. Your teacher may have you take photos of your plants at each data point as part of your data collection and record keeping.
8. Summarize on your data collection and reporting sheets your individual understandings of trait dominance, additive genes, epistatic genes, single-locus traits, and quantitative trait loci.
9. Summarize on their data collection and reporting sheets your analysis of the physical qualities of the three different bean plants you have grown and how their pod traits relate to trait dominance, additive and epistatic genes, single-locus traits, and quantitative trait loci.
10. Grow the plants to harvest and see if any cross-pollination occurred. If so, discuss with your class natural selection as it has occurred in your bean garden with three different varieties of beans being grown together. If not, discuss what may have prevented cross-pollination from occurring among the bean varieties.

Genetic Trait Variation in String Beans-
Assignment 1 & 2 Student Instruction & Data Sheets

Name: ______________________________

Describe in the area below your observations about the similarities and differences among the three different types of bean seeds you've been given.

In the area below, log the sprout date of each of your bean plants.

Sprout Date	Plant
	Purple 1
	Purple 2
	Purple 3
	Yellow 1
	Yellow 2
	Yellow 3
	Green 1
	Green 2
	Green 3

Genetic Trait Variation in String Beans-
Assignment 1 & 2 Student Instruction & Data Sheets

Every week, write down your observations of your plants as they develop and grow. Note the appearances of their leaves, flowers, and bean pods.

Week 1:

Genetic Trait Variation in String Beans-
Assignment 1 & 2 Student Instruction & Data Sheets

Every week, write down your observations of your plants as they develop and grow. Note the appearances of their leaves, flowers, and bean pods.

Week 2:

Genetic Trait Variation in String Beans-
Assignment 1 & 2 Student Instruction & Data Sheets

Every week, write down your observations of your plants as they develop and grow. Note the appearances of their leaves, flowers, and bean pods.

Week 3:

Piagetian Level: Early Formal

Genetic Trait Variation in String Beans-
Assignment 1 & 2 Student Instruction & Data Sheets

Every week, write down your observations of your plants as they develop and grow. Note the appearances of their leaves, flowers, and bean pods.

Week 4:

Piagetian Level: Early Formal

Genetic Trait Variation in String Beans-
Assignment 1 & 2 Student Instruction & Data Sheets

Every week, write down your observations of your plants as they develop and grow. Note the appearances of their leaves, flowers, and bean pods.

Week 5:

Genetic Trait Variation in String Beans-
Assignment 1 & 2 Student Instruction & Data Sheets

Every week, write down your observations of your plants as they develop and grow. Note the appearances of their leaves, flowers, and bean pods.

Week 6:

Genetic Trait Variation in String Beans-
Assignment 1 & 2 Student Instruction & Data Sheets

Every week, write down your observations of your plants as they develop and grow. Note the appearances of their leaves, flowers, and bean pods.

Week 7:

Genetic Trait Variation in String Beans-
Assignment 1 & 2 Student Instruction & Data Sheets

Every week, write down your observations of your plants as they develop and grow. Note the appearances of their leaves, flowers, and bean pods.

Week 8:

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Every week, write down your observations of your plants as they develop and grow. Note the appearances of their leaves, flowers, and bean pods.

Week 9:

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Every week, write down your observations of your plants as they develop and grow. Note the appearances of their leaves, flowers, and bean pods.

Week 10:

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Every week, write down your observations of your plants as they develop and grow. Note the appearances of their leaves, flowers, and bean pods.

Week 11:

Genetic Trait Variation in String Beans-
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Every week, write down your observations of your plants as they develop and grow. Note the appearances of their leaves, flowers, and bean pods.

Week 12:

Genetic Trait Variation in String Beans-
Assignment 1 & 2 Student Instruction & Data Sheets

In the area below, in paragraph format, summarize your understanding of trait dominance, additive genes, epistatic genes, single-locus traits, quantitative traits, and multiple trait loci.

In the area below, in paragraph format, summarize your understanding of the data you collected on your bean plants as they have grown over the last 12 weeks, as your data appear to relate to what you have learned about trait dominance, additive genes, epistatic genes, single-locus traits, quantitative traits, and multiple trait loci.