Probability and Patterns of Inheritance

Lesson Overview

In this lesson, students will simulate the Mendelian genetics of a monohybrid cross by flipping coins. They will use the data collected, individually and as class, to compare the probability of phenotypes and genotypes for a single trait. Students will then compare the class findings from the coin toss activity to Mendel's findings. In conclusion, as students complete practice problems on Punnett squares, they will use mathematical and computational thinking to create and analyze a *probability outcomes* table for possible phenotypes and genotypes.

Alignment

Standard/Indicator Addressed

Standard 7.L.4 The student will demonstrate an understanding of how genetic information is transferred from parent to offspring and how environmental factors and the use of technologies influence the transfer of genetic information.

7.L.4A.4 *Use mathematical and computational thinking* to predict the probability of phenotypes and genotypes based on patterns of inheritance.

Science and Engineering Practices (as appropriate)

7.S.1A.5 Use mathematical and computational thinking to (1) use and manipulate appropriate metric units, (2) collect and analyze data, (3) express relationships between variables for models and investigations, or (4) use grade-level appropriate statistics to analyze data.

Students should also ask questions and define problems; analyze and interpret data; construct explanations and design solutions; plan and carry out investigations; develop, use, and refine models, engage in scientific argument from evidence; and obtain, evaluate and communicate information.

Crosscutting Concepts: Patterns, Structure and Function

Standard/Indicator Addressed

SCCCR Math 7.DSP.5 Investigate the concept of probability of chance events.

a. Determine the probabilities of simple events.
b. Understand that probability measures the likelihood of a chance event occurring.
c. Understand that the probability of a chance event is a number between 0 and 1.
d. Understand that a probability closer to 1 indicates a likely chance event.

e. Understand that a probability close to ½ indicates that a chance event is neither likely nor unlikely.
f. Understand that a probability closer to 0 indicates an unlikely chance event.

SCCCR Math 7DSP.6 Investigate the relationship between theoretical and experimental probabilities for simple events.

a. Determine the approximate outcomes using theoretical probability.
b. Perform experiments that model theoretical probability.
c. Compare theoretical and experimental probabilities.

Standards for Mathematical Practice (as appropriate)

Standard 1: Make sense of problems and persevere in solving them.

a. Relate a problem to prior knowledge.
b. Recognize there may be multiple entry points to a problem and more than one path to a solution.

Standard 2: Reason both contextually and abstractly.

a. Make sense of quantities and their relationships in mathematical and real-world situations.

Standard 3: Use critical thinking skills to justify mathematical reasoning and critique the reasoning of others.

a. Construct and justify a solution to a problem.
b. Compare and discuss the validity of various reasoning strategies.
c. Make conjectures and explore their validity.
d. Reflect on and provide thoughtful responses to the reasoning of others.

Standard 6: Communicate mathematically and approach mathematical situations with precision.

a. Express numerical answers with the degree of precision appropriate for the context of a situation.
b. Represent numbers in an appropriate form according to the context of the situation.
c. Use appropriate and precise mathematical language

Connections

Active Learning Strategies

- Most Important Point
- I Think/We Think
- Highlighting
- Whiteboarding (see attached)
- Pair Share
- Verbal Visual Word Association

Computational Thinking:

- Formulating problems in a way that enables us to use a computer and other tools to help solve them.
- Logically organizing and analyzing data
- Representing data through abstractions such as models and simulations
- Tolerance for ambiguity & the ability to deal with open ended problems
- The ability to communicate and work with others to achieve a common goal or solution

Content Connections

- Science
- Computational Thinking
- Mathematics
  This lesson develops student understanding of Punnett Squares and how they may be used as a mathematical tool to predict inherited genetic traits. This lesson correlates to several mathematics lessons in this unit of study: *What Are My Chances?* and *Exploring the Genetics of Albinism*.

Lesson Plan

Time Required – Two 60 minutes class periods
Disciplinary Vocabulary –probability, ratio, phenotype, genotype, heterozygous, homozygous, allele

NOTE: Students are studying theoretical and experimental probability of both simple and compound events in mathematics class. In science class we use the terminology predicted or expected outcome and the actual outcome to represent the same concepts.

Materials Needed:

- Video: ***"Gregor Mendel"*** **https://www.youtube.com/watch?v=cWt1RFnWNzk**
- 2 coins for each pair of students

- Masking tape
- Coin Toss handout (attached)
- Mendel's findings Handout (attached)
- Highlighters
- Whiteboards or white card stock paper inserted in a clear plastic sleeve (paper protectors)
- Dry erase markers
- Paper towels or Tissue or Dry Erasers

Formative Assessment Strategies: Students will be assessed by questioning, lab responses, group dialogue, I Think/We Think responses, Punnett square practice, and student reflections.

Computational Thinking: This lesson addresses computational thinking by allowing students to interact with authentic data to organize and analyze data about phenotypes and genotypes, represent the data in a probability outcome table, use evidence, apply logic, and construct arguments for their proposed explanations, and evaluate and communicate the information scientifically.

Misconceptions:

- A dominant trait does not mean "more potent," and recessive does not mean "weaker." The terms simply refer to the visible trait, the phenotype.
- Students may confuse what has happened with what may happen.
- Students may believe that because an event has recently happened it has a high probability of reoccurring.

Engage

- Show the video on Gregor Mendel (4:41) **https://www.youtube.com/watch?v=cWt1RFnWNzk**
- Have students write down their Most Important Point (MIP) from the video. Ask students to stand, locate a partner, and share their MIPs.
- Tell students that today they will be using mathematical and computational thinking to predict the probability of phenotypes and genotypes based on patterns of inheritance.
- Ask students what probability means and where they have heard that word. Ask students what a ratio is and where they have seen or used that term before.
- Give the following definitions for **probability**. In general terms, probability is the likelihood of something happening and in mathematical terms, **probability** is the extent to which an event is likely to occur, measured by the **ratio** of the favorable cases to the whole number of cases (trials) possible.
- As we complete today's lesson, think about how you might analyze the results of a monohybrid cross based on patterns of inheritance and represent this information in mathematical terms.

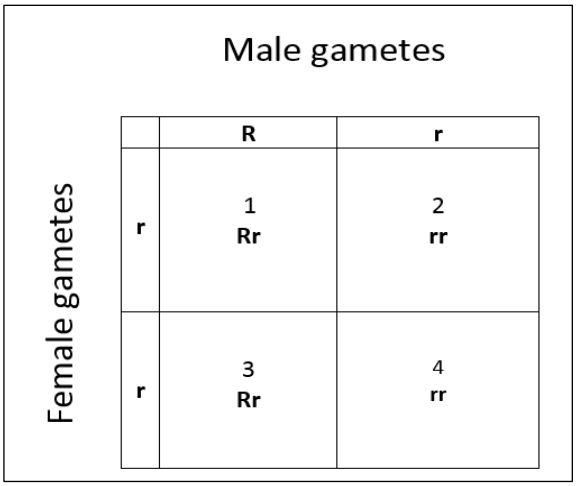
Explore

- Students should work in pairs to complete the coin toss activity.

- Distribute the **Coin Crosses handout** to students and review the procedure listed below**:**
    1. Gather masking tape & two coins.
    2. Place a piece of masking tape on each side of two coins.
    3. Write a T (for tall plants) on one side of each coin and a t (for short plants) on the other side.
    4. Toss both coins together 20 times. Record the letter combination that you obtain from each toss.
- Students should answer the analysis and conclusion questions with their partner.
- Create a data table on the board for the class result (answers to questions 1 and 2 on the Coin Cross handout).
- Have the class analyze the class results for how many plant offspring were likely to be tall and how many plant offspring likely to be short?
- Give out the **Mendel's Findings handout** (attached).
- Use the **I Think, We Think** Strategy to read the passage provided.
- Begin by having students record their initial, individual ideas about Mendel's findings.
- Organize students into small work groups. Provide time for the small groups to engage in discussion and argumentation based on their I THINK ideas.
- Each student should record the ideas that result from the group discussion. Ideas should include those on which the group agrees, as well as those on which the group is unable to reach consensus.
- Listen nonjudgmentally as the groups work and encourage as many ideas as possible. Bring the small groups together for whole class discussion, pointing out the similarities and differences in student thinking.
- Keep a record of ideas (The Class Thinks) to refer to throughout instruction, particularly as they change or are modified.
- Compare the class results from the coin toss activity to Mendel's actual results. How close did **you and your partner** come to the actual ratio Mendel found for dominant and recessive? How close did your **class** come to Mendel's findings?

Explain

- Write the following word problem on the board. Have students copy the problem on a piece of paper. **Problem:** *A male pea plant with round seeds has the genotype Rr. You cross this plant with a female wrinkled-seed plant, genotype rr. What is the probability that the offspring will have wrinkled seeds? (Use a Punnett square to prove your answer and give a probability table).*
- Model for students how to underline (**highlight**) or label the key information or terminology in this problem. An "X" in a genetics problem indicates that the two organisms are involved in a genetic cross. If the sex of the parents are not listed, choose one to be the male and the other to be the female.
- *Set up the Punnett square using the example below.*



- First, write the genotype and phenotype of the parents:
  Male genotype: Rr (heterozygous)
  Male phenotype: round seeds (dominant trait)
  Female genotype: rr (homozygous)
  Female phenotype: wrinkled sends (recessive trait)

- Next write down the possible genetic contributions (**gametes**) that the parents can produce. Write these on the top and side of the Punnett square
  Male Gametes (pollen): R or r
  Female Gametes (egg): r or r

- Now complete the Punnett square by writing the alleles from the gametes in the appropriate boxes. Have students copy this Punnett square.
- Next, create a "Probability Outcomes" table to find out the possible offspring from this genetic cross. *In math class, students call this a matrix. Ratios are a review for 7th grade students.*

Probability Outcomes Table

Genotype	Ratio	Percent (%)	Phenotype	Ratio	Percent (%)
Rr	2:4 or $\frac{2}{4}$	50%	Round	2:4 or $\frac{2}{4}$	50%
rr	2:4 or $\frac{2}{4}$	50%	Wrinkled	2:4 or $\frac{2}{4}$	50%

- ***After discussing the first cross, have students use their Whiteboards to set up the Punnett square and Probability Outcomes Table for the genetics problem below.***
  - A cross of two heterozygous, round seed plants (Rr X Rr).

ANSWERS:

	R	**r**
R	1 **RR**	2 **Rr**
r	3 **Rr**	4 **rr**

Probability Outcomes Table **ANSWERS:**

Probability Outcomes Table

Genotype	Ratio	Percent (%)	Phenotype	Ratio	Percent (%)
RR	1:4 or $\frac{1}{4}$	25%	Round	1:4 or $\frac{1}{4}$	25%
Rr	2:4 or $\frac{2}{4}$	50%	Round	2:4 or $\frac{2}{4}$	50%
rr	1:4 or $\frac{1}{4}$	25%	Wrinkled	1:4 or $\frac{1}{4}$	25%

- Have students **pair share** their whiteboards answers. As students are working, the teacher circulates the classroom and has guided conversations with student pairs as a formative assessment.
- Suggestion: If technology is available, have students take a picture of their whiteboard answers and email to the teacher. The teacher can use this snapshot as an overview of student understanding.
- Review the answers (see above) with the class.
- Ask this question: Based on the data in your probability outcome table, what would be the ratio of round to wrinkled seeds phenotype? What would be the percentage? 3:4 or 75 %

Word	Visual Representation
Definition	Personal Association/Examples/Characteristics

- Students use the **Verbal Visual Word Association** strategy to summarize their learning on patterns of inheritance and probability, through the use of Punnett squares.
- Use the visual above to guide students in setting up how the information should be written.

1. Direct students to use a piece of paper to draw a rectangle divided into four sections.
2. In the upper-left box of the rectangle, students should write the vocabulary word. (Punnett Square)
3. In the box below, they should write the definition. (Instruct students to write the definition in their own words instead of copying from a "glossary.")
4. Next, students will need to draw a visual representation in the upper-right box of the rectangle (next to the vocabulary word).
5. For the final box (lower right), have students write their own personal association, an example or characteristic that relates to the vocabulary term.

Lesson adapted from

This activity sheet in this lesson is adapted from:

- Kohn, C. A. (2012, February 7). Goat Coin-flip genetics. Retrieved April 25, 2017, from https://communities.naae.org/docs/DOC-4743
- Exploring Genetics. Across the Middle School. Science and Math Curricula. Dr. Jeffrey Batten. Carol Cutler White, Editor. 2nd Edition. July 2014. (n.d.). Retrieved April 25, 2017, from http://www.greenomes.org/ (Activity 4 Science))
- Mendel's Findings Handout Information found Pecore, J., & Nagle, C. (2016). From Mendel to Me: Constructing Genetics Knowledge Through Historical Problem-Based Learning. Science Scope, 039(06), 27-34. doi:10.2505/4/ss16_039_06_27

Coin Toss Activity

Coin Toss	First Coin	Second Coin
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

Procedure

1. Gather masking tape & two coins.
2. Place a piece of masking tape on each side of two coins.
3. Write a T (for tall plants) on one side of each coin and a t (for short plants) on the other side.
4. Toss both coins together 20 times. Record the letter combination that you obtain from each toss.

Analyze & Conclude

1. How many of the offspring would be tall plants?

2. How many would be short plants?

3. How does this experiment demonstrate probability?

4. How does this experiment demonstrate Mendel's work on pea plants?

Adapted from Kohn, C. A. (2012, February 7). Goat Coin-flip genetics. Retrieved April 25, 2017, from https://communities.naae.org/docs/DOC-4743

Mendel's Accomplishments: Pea Plants
Part A:
From the summer of 1856 through 1863, Mendel researched on pea plants because of their purity and more easily observable characteristics. His research question was "*How many different forms would result from the random fertilization of two kinds of pea plants? "* He hypothesized that *the existence of factors for each characteristic responsible for different variations of a trait doesn't occur together*.

In other words, Mendel wondered if you crossed a long stem pea plant with a short stem pea plant, could you predict the result of creating a long stem or short stem pea plant? Mendel carried out his experiment and collected the following data.

Characteristic					**Ratio**
Seed Shape	Round	5,474	Angular	1,850	2.959:1
Pod Color	Green	428	Yellow	152	2.816:1
Stem length	Long	787	Short	277	2.841:1
TOTAL	Dominant	6,689	Recessive	2,279	2.935:1

Data are used to inform conclusions and help scientists learn new things. Take a close look at Mendel's data. What patterns do you see in the data? How can the data help explain the traits and how they are inherited?

I Think (My Observations of patterns)

We Think (Observations with a Partner or Group)

Pecore, J., & Nagle, C. (2016). From Mendel to Me: Constructing Genetics Knowledge Through Historical Problem-Based Learning. Science Scope, 039(06), 27-34. doi:10.2505/4/ss16_039_06_27

Whiteboarding

Whiteboarding is a strategy used as a formative assessment utilized pre-lesson, during instruction, or at the end of the lesson. This is a quick way to implement a short question/answer session where all students need to participate. This creates an inclusive environment where all students are expected to participate. Answers may be in word, number, or picture form. Writing on the whiteboard allows students to go back and revise, if the instructor wants that to be a part of the process.

How to implement the strategy:

1. Teacher will hand out white boards and dry erase markers.
2. The teacher asks a question or poses a problem.
3. Students work either independently or with a partner/group.
4. Teachers give students a prescribed amount of time to answer.
5. Students hold up their answers at the same time.
6. The teacher then asks students to support their answers with evidence.

*Note, teacher modeling is the most effective way to demonstrate the process.

Adapted from:

• • Keeley, Page & Tobey, Cheryl R. (2011). *Mathematics Formative Assessment: 75 Practical Strategies for Linking Assessment, Instruction, and Learning. Corwin & NCTM*