High School

MATH & SCIENCE LESSON 4

Hilleman & Vaccines

GUIDE OVERVIEW

Hilleman & Vaccines: Connecting Culture to Scientific Curiosity

LEARNING GOALS

This series of lessons will allow students to use mathematics to improve scientific and mathematical literacy, and combine the two to help students understand where humans are in the context of a pandemic, especially during the development of an entirely new vaccine. Students will understand the development and use of a variety of vaccines.

WHERE DOES THIS FIT INTO YOUR CURRICULUM?

MATH

Using simulations as models and then applying computational thinking to understand processes

Using probability and statistics to understand population dynamics

SCIENCE

Understanding the spread of diseases in populations

Understanding the development and use of a variety of vaccines and the process of achieving herd immunity to stabilize the human population during a pandemic

Understanding how genetic mutations occur and their effect on organisms and the stability of a system

MATHEMATICAL PRACTICES

Make sense of problems and persevere in solving them.	Reason abstractly and quantitatively.
Construct viable arguments and critique the reasoning of others.	Model with mathematics.
Use appropriate tools strategically.	Attend to precision.
Look for and make use of structure.	Look for and express regularity in repeated reasoning.

MATHEMATICAL STANDARDS

Statistics and Probability: Interpreting Categorical and Quantitative Data (S.ID1,2,3, 5, 6a,6b, 6c).	Conditional Probability and the Rules of Probability (S.CP 1,2,3,4,5,6,7,8).
Making Inferences and Justifying Conclusions (S.IC, 1,2,3,4,5,6).	Using Probability to Make Decisions: (S.MD 6,7).

MONTANA SCIENCE STANDARDS

Crosscutting Concepts: Cause and effect; proportion and quantity, and systems and system models.

Science and Engineering Practices: Developing and using models; analyzing and interpreting data; using mathematics and computational thinking, constructing explanations as it applies to science.

LS2. A: Use mathematical or computational representations to support arguments about environmental factors that affect carrying capacity, biodiversity, and populations in ecosystems.

LS3.B: Make and defend a claim based on evidence from multiple sources that inheritable genetic variation may result from:

- New genetic combinations through meiosis
- Viable errors occurring during replication
- Mutations caused by environmental factors

LS3. B: Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

Lesson 4

Herd Immunity

Hilleman & Vaccines

LESSON INSTRUCTIONS
Lesson 4: Herd Immunity

ENGAGEMENT

Students will apply what they've learned by completing the Herd Immunity activity (student pages 191-194). Students will run each simulation 5 times, record each result, then display the results in a bar graph.

OBJECTIVES

Students will consider

1. What does the spread of a new virus look like?
2. What does the spread of a virus look like with different vaccination percentages?
3. What does the spread of a new variant look like with an existing vaccine?
4. What does the threshold of herd immunity do for a population when it is met?

PREPARATION

- Make copies of the student pages, one per student
- Review the "Herd Immunity" Simulation, available on NPR at: https://www.npr.org/sections/health-shots/2021/02/18/967462483/how-herd-immunity-works-and-what-stands-in-its-way

ASSESSMENT

Students will share graphs and discuss trends observed, then answer the questions on student page 193.

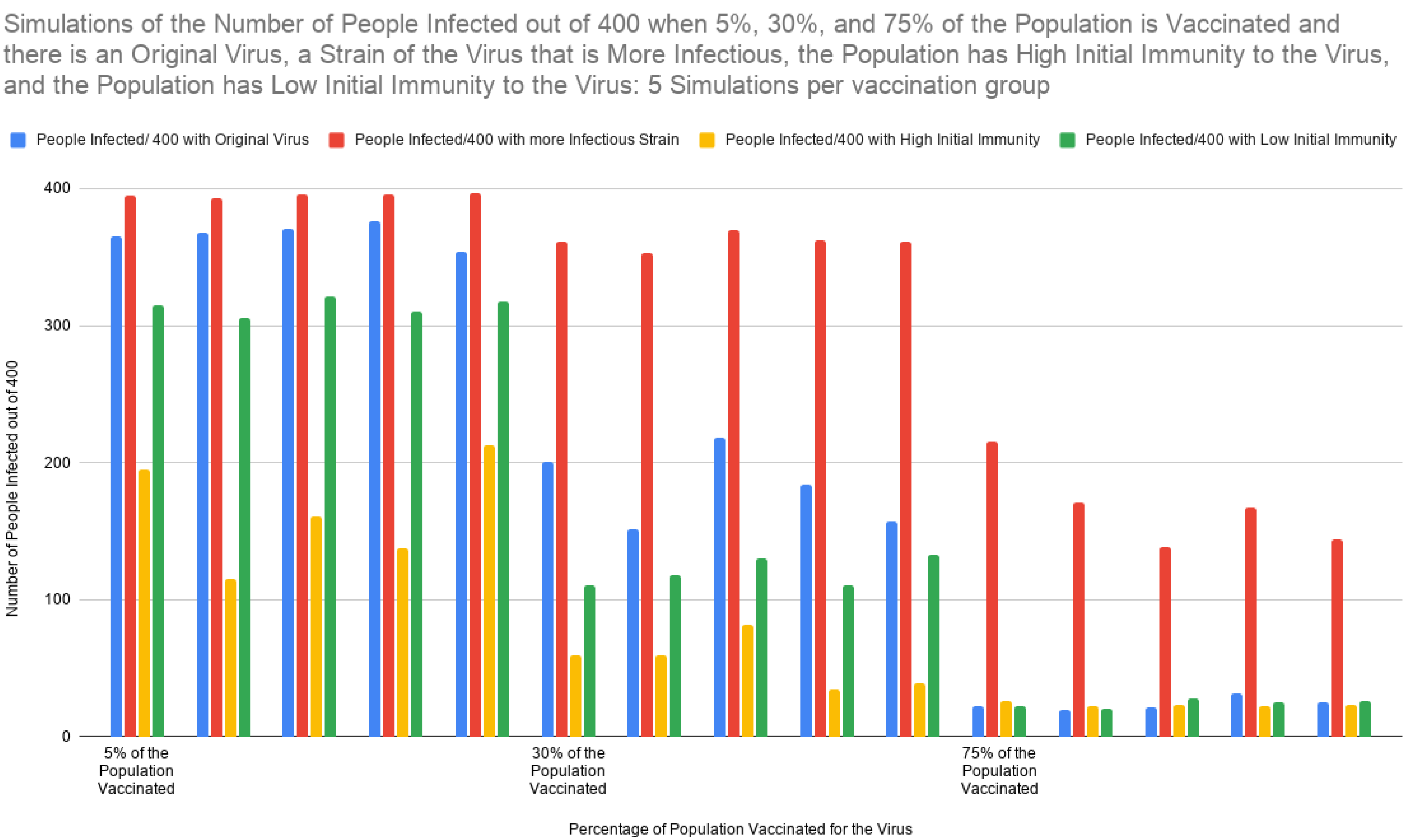
Sample Graph Table

Simulations of the Number of People Infected out of 400 when 5%, 30%, and 75% of the Population is Vaccinated and there is an Original Virus, a Strain of the Virus that is More Infectious, the Population has High Initial Immunity to the Virus, and the Population has Low Initial Immunity to the Virus: 5 Simulations per Vaccination Group.

Vaccination Groups	People Infected/ 400 with Original Virus	People Infected/400 with more Infectious Strain	People Infected/400 with High Initial Immunity	People Infected/400 with Low Initial Immunity
5% of the population vaccinated	365	395	195	315
	368	393	115	306
	371	396	161	321
	376	396	137	310
	354	397	213	318
30% of the population vaccinated	201	361	59	110
	151	353	59	118
	218	370	82	130
	184	362	34	110
	157	361	39	133
75% of the population vaccinated	22	215	26	22
	19	171	22	20
	21	138	23	28
	31	167	22	25
	25	144	23	26

(Note: Graph on following page)

SAMPLE GRAPH EXAMPLE



What is Herd Immunity?

Herd immunity is a threshold at which enough of a population is immune to a disease to make the spread of the disease unlikely (McPhillips, 2021), or the number of people who are still vulnerable is too small to have continued outbreaks. In general, epidemiologists do not speak of herd immunity without vaccinations, because immunity through exposure has never resulted in herd immunity before. Medical professionals prefer to call it herd protection, because immunity does not just happen for everyone, but if a large portion of the population is protected, then the most vulnerable people, who cannot use or respond to the vaccine, are less likely to contract the disease (Aschwanden, 2020).

Based on other coronaviruses that cause the common cold, immunity lasts for approximately one year. In that scenario, the population will not reach herd immunity through transmission. For COVID-19, we do not actually know yet. In a community, when the number of people who are immune or vaccinated falls below the herd immunity threshold, outbreaks can happen in that community (Aschwanden, 2020). At this time, approximately 70-85% of the U.S. population would need to be infected and recover from COVID-19 or be vaccinated. By the end of 2020, about one third of the U.S. population is estimated to have been infected (McPhillips, 2021), which has resulted in 511, 839 deaths (CDC, 2021). As of April 14, 2021, 23.1% of the U.S. population has been entirely vaccinated (CDC, 2021).

There is still much to be accomplished to prevent the loss of another 500,000 lives in this country alone, not to mention the aftermath for the people who suffer long-term effects from the virus. The threat of new variants can change the herd immunity threshold, so the current goal is to get people vaccinated before these variants spread too far (Aschwanden, 2021). Below is a simulation of what the spread of a new virus looks like in different scenarios and it highlights the importance of vaccination programs and why they are so successful (Wilburn & Harris, 2021). As you view the simulation, consider how many lives were saved by Dr. Hilleman who developed 40 vaccines, including eight of the 14 common vaccines received by children today (Moore, 2021).

Run Simulations of a New Virus and Graph the Results

1. Open this website to view the simulation and consider exactly what is being studied in this simulation.
https://www.npr.org/sections/health-shots/2021/02/18/967462483/how-herd-immunity-works-and-what-stands-in-its-way

The simulation at the top of this page is the original virus and should be the first simulation students run. The simulation that says number one is actually the second simulation of the four.

2. Open a Google Sheet or an Excel Spreadsheet to create your data table and graph. Start by giving your spreadsheet a title with your last name at the end.

Adding students' last names makes it much easier to know whose is whose in a digital format, especially when they pull them up to present.

3. Begin creating your data table by placing a title at the top of it. The title should include all of the types of data being collected. You will find this information by studying the simulation.

See the example graph below. For younger students, this is a lot of data with lots of sample groups, so you may want to assign them Google Sheets that have the data table labeled already.

4. Run the first simulation five times and record the data in your data table. The first simulation is for the original virus and has 3 different vaccination groups. Make sure you record data for all three vaccination groups.

Notice that the first simulation has the original virus with three different vaccination percentages. The students will be writing in data for three sample groups each time they run this simulation. The same is true for the next three simulations.

5. Continue doing this for the next three scenarios (more infectious variant, a population already heavily exposed, a population with low initial exposure).

They need to run each scenario five times.

6. Create a graph of your data. Make sure the graph has a title and both axes are clearly labeled and have units of measurement where needed. This graph will need a legend.

In Google Sheets, students can highlight the parts of the data table that they want to graph, and then they "insert" a "chart". They will want to choose the column graph. To edit the title and axis labels, they can click on the graph. Three dots will appear in the top right corner. Click those dots and choose "edit chart", then "customize", then select "chart and axis titles". From there students can use the drop-down menu to choose which title/axis they need to adjust.

Follow-Up Questions

1. Does your data make sense to you? Why?

The data makes sense because as more people were vaccinated or exposed, fewer people were becoming infected, and the more infectious strain caused the greatest amount of infection. This helps students examine their data and reread parts of their graphs (for example, each axis label), and they think critically about what each bar represents.

2. In which scenario did the least amount of people become infected? Be very specific about the details of the scenario.

Again, this helps students examine what the graph really shows, but the discussion may also help them understand all of the factors that contribute to immunity.

3. What insights do you gain about new variants from the second simulation?

New variants can significantly reduce the effectiveness of a vaccination program. The faster we can get people immune via vaccination, the more we reduce the chances of new variants emerging. New variants arise when the virus is allowed to replicate rapidly. This process leads to copying mistakes--some of those can become beneficial to the virus.

4. If vaccinating 75% of the population is considered to be herd immunity, why are there still people being infected in the first and third simulations at 75% of the population being vaccinated?
Herd immunity does not make everyone immune; it only helps to slow the spread enough to hopefully protect the vulnerable. It does not mean that everyone is immune. The goal is to prevent devastating outbreaks. In some cases, diseases can be eradicated, but they will come back if vaccination programs stop.

5. If 75% of the 400 people are vaccinated, how many people could be infected in the first simulation? Did your data represent that in the first simulation? How do you know?
25% of the people could be infected so that is 100 people, but hopefully herd immunity leads to protection of some of those people. If the students find the mean value of the people who were infected, they can see how many people were infected. From the graph and data provided, the mean was 23.6 people who were infected with the original virus when 75% of the population was vaccinated. Approximately 76.4 additional people were protected.

6. If the vaccine has 94% efficacy like the current COVID-19 vaccine, and 75% of the population of 400 people are vaccinated, how many people could be infected out of 400?
If 75% of the population is vaccinated, then that is 300 people. If 94% of those people are protected from the virus, that is 282 people and 118 people could be infected. The herd protection seen in number five becomes very important here.

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