VaxImpact Simulator

A Data-Driven Investigation of Disease Transmission & Vaccination

PHENOMENON → What happens when community vaccination changes?

Scenario: A contagious disease enters a community such as a school. Some people are vaccinated and some are not. Use a computational model to investigate how changing vaccination coverage changes the pattern and size of an outbreak.

Driving Question

How does changing vaccination coverage affect the spread of an infectious disease in a community?

NGSS 3-DIMENSIONAL LEARNING TARGETS

SCIENCE & ENGINEERING PRACTICE	DISCIPLINARY CORE IDEA	CROSSCUTTING CONCEPT
Developing & Using Models Use a computational model to generate data, test relationships, and consider limitations.	LS2.A: Interdependent Relationships in Ecosystems Disease is one challenge that can affect populations; interactions among organisms help shape population patterns.	Cause & Effect Use evidence to explain how changing one component of a system can change another.

Your investigation pathway: Ask a testable question → make a prediction → use the model → collect repeated data → graph the pattern → explain what the evidence shows → consider model limitations.

Model Limitation

This simulation is a simplified model. Its numerical outputs are not medical recommendations and should not be used to determine a real-world herd-immunity cutoff. The purpose is to investigate relationships under the model's assumptions.

Part I — Explore the Simulation & Ask a Testable Question

NGSS focus: Asking Questions • Developing & Using Models

1. WHAT IS INCLUDED IN THE SIMULATION?

The simulator (which can be found here: http://vaxshield.org) represents a simplified community in which disease can spread among people. You can change selected input variables and observe how the outbreak changes. The main simulation panel shows the modeled spread, and the Epidemic Timeline shows how cases change over time.

Input	What you can change	What to look for
Transmission rate	How readily infection spreads in the model.	Does the outbreak become faster/larger or slower/smaller?
Infectious Period	Days an infected person remains contagious and able to infect other individuals.	Does the outbreak last longer or shorter?
Mortality rate	The proportion of infected people who die in the model.	How does this change deaths without necessarily changing transmission?
Population density	How closely/frequently people are modeled as interacting.	Does increased contact opportunity change the outbreak?
Vaccine effectiveness	How well vaccination protects vaccinated people in the model.	How does protection affect infection among vaccinated people and the wider outbreak?
Vaccination rate	The percentage of the community that is vaccinated.	How does changing coverage affect outbreak size?

Outputs you can observe: the visual simulation and the Epidemic Timeline, which displays currently infected, total infected, and susceptible cases over time. Use the Learn More feature for additional information about the controls.

2. Explore before you test

Change one variable at a time and record what happened. These are observations, not yet your formal experiment.

What did you change? What happened to the outbreak?

3. Write a testable question

A testable question identifies one independent variable you will change and at least one dependent variable you will measure. For example: "Does the amount of sunlight a tomato plant receives change how fast it grows?" (You can measure the sunlight and growth). Write a testable question below.

Now identify the parts of your question:

Independent variable What will I change?	Dependent variable(s) What will I measure?	Controls What will stay the same?

4. Why should you change only one independent variable at a time in a fair test?

Note: Students can complete the additional lesson plan titled "You're the Epidemiologist: Design and Explore Your Own Experiment Investigating Disease Outbreak" if they would like to investigate their testable hypothesis.

Part II — Plan & Carry Out a Controlled Investigation

Change vaccination rate while keeping the other simulator settings constant.

BASELINE SETTINGS

Transmission rate:	90%	Infectious Period:	14 days
Mortality rate:	1%	Population density:	90%
Vaccine Effectiveness:	97%	Independent Variable:	Vaccination rate

1. Make your prediction

I predict the peak infections and total infections will ☐ increase ☐ decrease

because...

2. Run 3 trials at each vaccination rate. **The simulator ends on its own after there are no more infectious individuals in the community.** Record the outcomes measured each time after the simulator ends. Repeated trials help you identify patterns despite randomness in the model.

Experiment: 65% vaccination

Trial	Peak infections (most sick at once)	Total infected	% vaccinated sick	% unvaccinated sick
1				
2				
3				
Average				

Experiment: 80% vaccination

Trial	Peak infections (most sick at once)	Total infected	% vaccinated sick	% unvaccinated sick
1				
2				
3				
Average				

Experiment: 95% vaccination

Trial	Peak infections (most sick at once)	Total infected	% vaccinated sick	% unvaccinated sick
1				
2				
3				
Average				

Part III — Analyze the Data

NGSS focus: Analyzing & Interpreting Data • Using Mathematics & Computational Thinking

STEP 1 — GRAPH YOUR RESULTS

Using the space below, graph the average peak and total infections you calculated in Part II.

Recommended graph

x-axis = vaccination rate (%) y-axis = average total infected
Your graph should have a clear title, labeled axes, units, and average peak and total infections for all three vaccination rates.

Title: _____

3. Describe the trend you see in the graph. What happens to outbreak size as vaccination rate changes?

Part IV — Predict, Compare & Explain

Use the pattern in your data to make a prediction at 90% vaccination.

90% PREDICTION

These benchmark values were generated from the simulation under the same baseline settings used in Part II. Use them to judge the scale of your prediction.

Metric	85% benchmark	Your 90% Estimate	95% benchmark
Average peak infections	67.45		4.64
Average total infected	205		7.55
% vaccinated who become sick	5.68%		0.19%
% unvaccinated who become sick	62.00%		7.60%

After entering your 90% estimates: Were your estimates for peak infections and total infections closer to the 85% benchmark or the 95% benchmark?

☐ **Closer to 85%** ☐ **Closer to 95%** ☐ **About equally close**

Explain why you chose this:

4. Conduct 5 trials at 90% vaccination rates and calculate the average across the 5 trials.

Trial	Peak infections (most sick at once)	Total infected	% vaccinated sick	% unvaccinated sick
1				
2				
3				
4				
5				
Average				

5. Return to your original prediction. Were your predictions that peak infections and total infections would increase or decrease supported by your experiment? Use at least one result from your data.

Part V — Analysis Questions

Use your results, the simulator, and the information in each prompt to explain what the model shows about disease transmission. These questions also ask you to consider how real-world conditions could change the pattern.

1. Vaccine effectiveness
How may vaccine effectiveness influence disease transmission? Please write a hypothesis and explain how you would test this with the simulator, based on how you tested vaccine rates in Part II?

2. Indirect transmission
Many diseases can spread through indirect contact with others, such as germs that can live on door handles. For example, measles can remain in the air for 2 hours after a person has left a room, which is one of the factors that makes measles highly contagious. Considering this, how might this change the results of the simulator?

3. Unvaccinated decisions can affect other people
John has decided that he doesn't want to receive an annual flu vaccine and believes that being unvaccinated is a decision that only affects himself. Based on the simulation and what you've learned above, do you agree or disagree with this reasoning? Explain why or why not.

4. Protecting people who cannot safely receive a vaccine
Sarah is immunocompromised and is a part of the very small percentage of people who can not safely receive a vaccine. Additionally, if she does get an infectious disease, such as the Flu or Measles, she has a much greater risk of severe complications. Explain how John's decision can influence Sarah's health, if it does at all.

5. Hospital Strain

One important variable not included in this simulation is hospital strain. How might vaccination rates indirectly influence hospital strain (number of hospitalized people at any given time)? Would you expect this to also affect the mortality rate if hospitals and healthcare professionals are unable to manage the volume of cases occurring within a flu season? Hint: Consider what happened during the COVID-19 Pandemic when resources became scarce. You can use this article if it helps: Impact of Hospital Strain on Excess Deaths During the COVID-19 Pandemic, CDC

6. Real communities are not isolated

This simulator assumes that people in a community (such as a school) are isolated from everyone else and can only become infected by others within that community. Would you expect such an isolated scenario to occur in real life? Explain why or why not, and how this might alter patterns of disease transmission.

7. People are not mixed randomly

In real life, individuals often spend time in the same groups, such as friend groups, classrooms, job offices, or even sitting at a cafeteria table. This also means that unvaccinated people may be around other unvaccinated people more often (such as within a family). This simulator does not consider this and instead mixes everyone randomly. How do you think this difference would affect how a disease spreads? Would outbreaks become larger, smaller, or stay the same? Explain your reasoning.

8. Multiple variables can change at once

In Part II, you changed only one variable (vaccination rate). In real-world scenarios, multiple variables change at once. Choose one additional variable (e.g., population density or transmission rate) and explain how changing it, together with the vaccination rate, might alter the outbreak differently than changing either one alone.

OPTIONAL EXTENSION

Read this paper (Measles Resurgence and the Fragility of Herd Immunity: Implications for Pediatric Infectious Disease Practice) discussing measles resurgence due to declining vaccine rates and the implications of this resurgence for infectious diseases. Then compare what the real-world evidence shows with what your simulation predicts.