The Epidemiology of Influenza

New Mexico Adventures of
Supercomputing Challenge
Final Report
April 6, 2005

Team 059
Santa Fe High School

Team Members

Caitlin Armijo
Dahlia Musharrafieh

Teacher

Anita Gerlach

Project Mentor

Atty Mullins

Table of Contents

1 Executive Summary

Influenza, otherwise known as the flu, is a contagious respiratory illness caused by influenza viruses. The flu can cause mild to severe illness, and can be fatal. Certain people, such as older people and people with health conditions, are at a high risk for serious complications from the flu virus. Fifty-six million Americans get the flu each year and more than 36,000 people die a year from the flu illness. Examining the epidemiology of influenza will lead to a better understanding of how to minimize the infection rate and how to prevent an influenza epidemic.

To calculate and analyze the epidemiology of influenza, we created a model, which includes the following factors: infection rate, recovery rate, death rate, vaccination rate, vaccination efficiency, susceptibility, and transmission rate. We will model the population of Santa Fe High School through StarLogo. This model will not be completely accurate in portraying the spread of influenza in an actual population because the population of Santa Fe High School consists of only one age group.

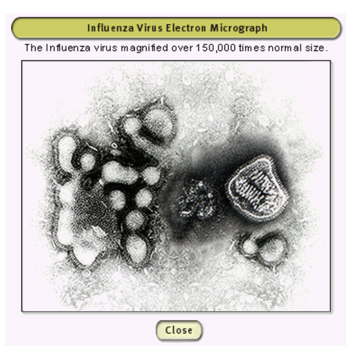
The results will enable us to decide what percentage of the population should be vaccinated and who specifically, as in susceptibility, should be vaccinated to prevent an epidemic from occurring. Also, the model will allow us to determine whether vaccinating susceptible people plays a crucial role in the fight against the spread of influenza.

2 Introduction

The Epidemiology of Influenza affects us each day because it is a daily risk and is a threat to our health. Discovering the best way to control the spread of influenza will be beneficial to the Santa Fe High School community. This project will also help us to better understand diseases and their spread. We will also address the issue of how students come to school ill and are in close proximity in the closed classrooms. The concept of this project can be applied to numerous situations involving diseases and certain illnesses.

The StarLogo simulation of Santa Fe High School consists of agents in the form of people representing various conditions, such as susceptibility and vaccination intake. In the StarLogo replication of the Santa Fe High School population, the numbers and percentages used in the slides are actual data found in our research, which enables our simulation to produce realistic results.

In the future, we fear that the influenza virus may indeed become an epidemic, such as the avian flu, that will result in the deaths of millions of people. Our study will allow us to know how to control such a disaster from occurring and can be used for future analysis of any disease. Our model, graphs, data, and results enable us to view what could happen to a high school population if the influenza virus erupts and how we could stop this sudden outburst.



3 Specific Problem

The results in the StarLogo model will inform us of how the Influenza virus will spread in a specific location, how an Influenza epidemic can occur, and how to stop an epidemic. The various factors, such as infection rate and susceptibility, are considered in the model for the results to be rational and accurate. The “vaccination-efficiency slide,” the “percentage-infected” and the “number slide” are actual statistics and numbers. The model will allow us to know how to treat a population, in which an outbreak of Influenza has occurred. For example, the model includes a “percentage-vaccinated slide” to vary the number of people vaccinated, which enables us to determine the amount of people that should be vaccinated to control the Influenza virus. The specific answer we intend to find with the aid of the StarLogo model is how to handle and stop the Influenza virus in an isolated population.

3.1 Limits and Assumptions

In our model, we had to set limits and make assumptions for our calculations and analysis to be correct. We limited the population to represent half the population of the students at Santa Fe High School, instead of the population of Santa Fe, because we did not want to make the StarLogo model too complex to operate with several age groups, a factor of susceptibility for the Influenza virus. The population is also isolated because the students’ interactions with other people outside the school and people in younger or older age groups are difficult to analyze and estimate.

We assume, in the model, that one person dies a day on average from complications with the Influenza virus. The model presumes that whoever has not died from the Influenza virus, recovers. For logical reasons, we also assume that the number infected is fifty percent of the total 740 people.

3.2 Process

To first make a simple, running model on the Epidemiology of Influenza, we made slides for the percentage of infected students, the recovery rate, and the transmission rate of the Influenza virus. We later add slides for susceptibility, the percentage of students vaccinated for the Influenza virus, and the vaccination's efficiency. These factors play important roles in the process and the velocity that the Influenza virus spreads in a population. The model will now mirror a population of students who have certain health conditions and which students decide to get the vaccination for Influenza. Most people recover from the Flu, however, some people die. To consider the amount of people who die and recover from the Influenza virus, we added slides labeled "recover-rate" and "death rate."

4 Results

4.1 Procedure

We ran StarLogo numerous times under several different conditions in order to obtain realistic results. Throughout the experiment, the infection rate was kept at fifty percent, the "vaccine efficiency" was kept at eighty percent, and the death rate at one person per day. The susceptibility rate was half of the infection rate, 25%. The number of students vaccinated was set equal to the susceptibility rate. The recovery rate was set equal to the transmission rate. The second setup had half of the infection rate equal to the susceptibility rate, 25%. Only about half of the susceptible students were vaccinated. The third setup of the model had the transmission rate set to 30% and the recover rate set equal to the susceptibility rate and the vaccination rate. The fourth and final setup had the transmission rate set equal to the infection rate and the recover rate, 24%, set equal to the vaccination rate. Most importantly the susceptibility rate, 34%, was set to be greater than the recovery rate and the vaccination rate. The results were obtained by analyzing how the graphs of the healthy students, the sick students, and the total population decreased or increased, also known as the slope. The graph representing the total number of dead students was also analyzed and recorded.

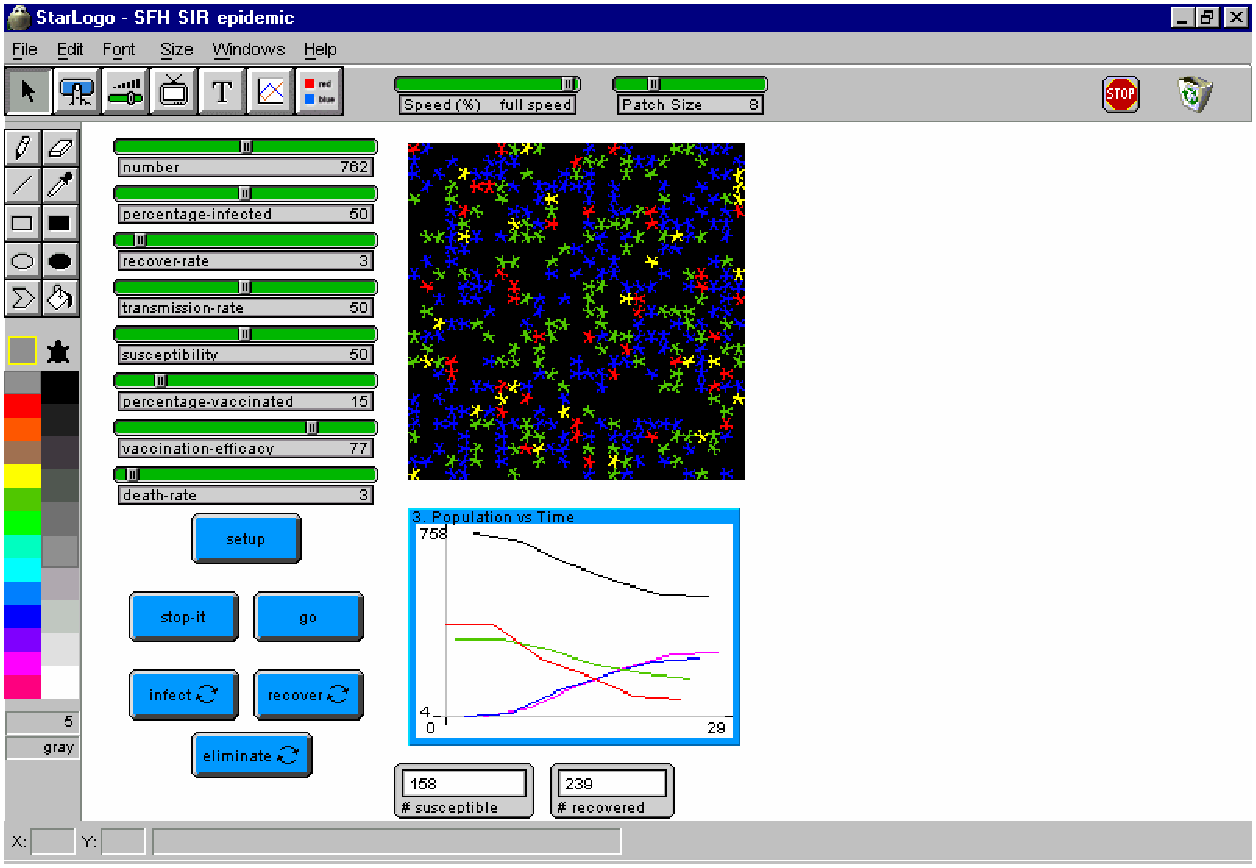
4.2 Outcome

The results from the first setup demonstrate that the healthy students tend to remain at a constant number of approximately 290 people. Also, as the number of sick people decreased, the death rate rose. The death rate increased as the recovery rate increased. At the half point of time, the number of sick students equaled the number of recovered students, and the number of dead students equaled the number of sick students. The second run maintained a constant number of healthy people once again. The recovery rate, however, increased drastically, and the death rate rose also. In the third running of the program, the number of sick people decreased severely, and the recover rate increased rapidly. The number of dead students decreased with the total population of students, and the number of healthy students decreased a small amount. For the fourth setup, the infection rate decreased at a fast rate and the recovery rate greatly increased. Again, in the fourth run, the number of dead students increased slowly with the total population.

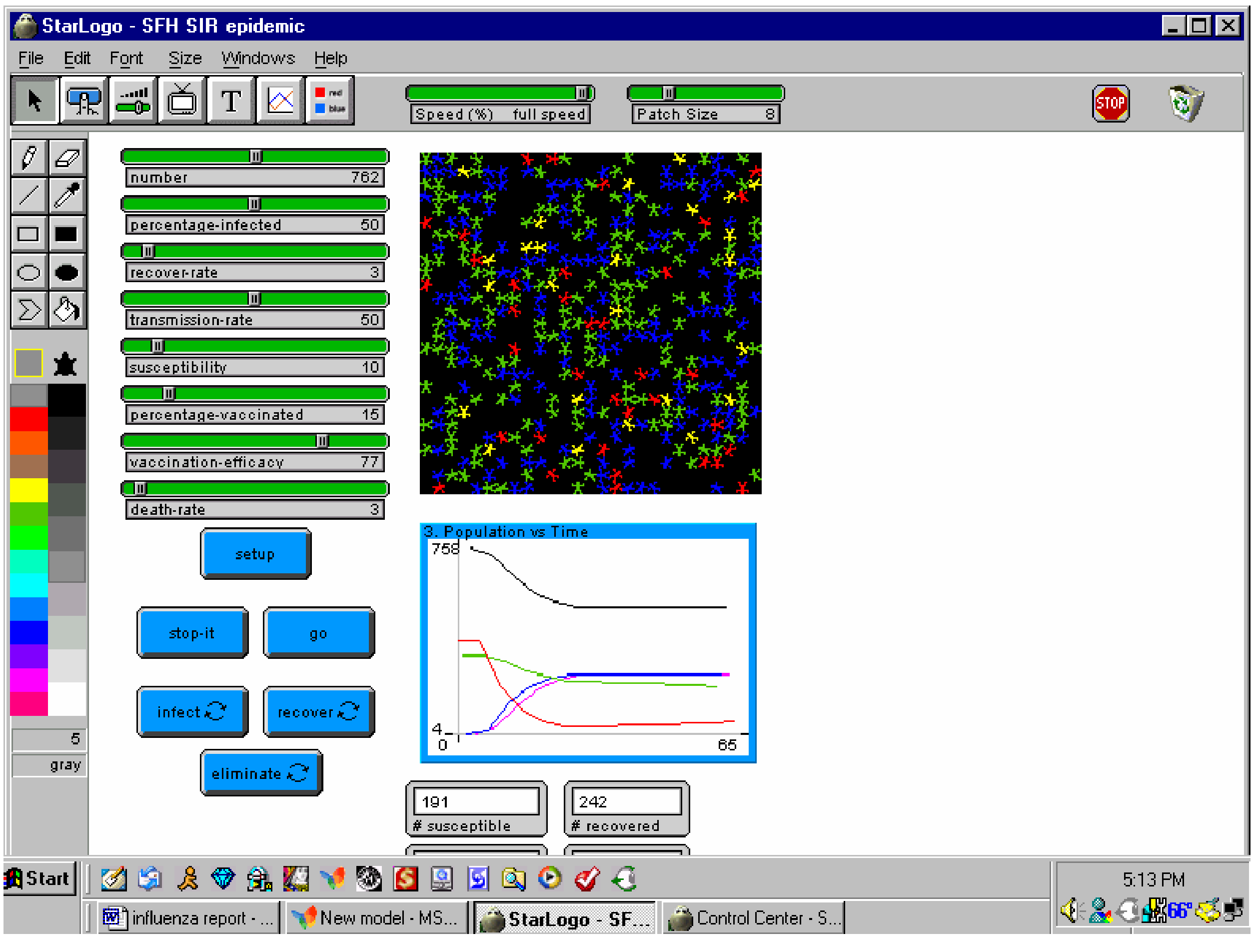
5 Discussion

Many different outcomes and situations were a part of the results of the model. The Influenza virus can effect an isolated population a unique way each time there is an outbreak of the virus. The StarLogo model represents the conditions, the circumstances, and the environment of a population that has acquired the Influenza virus.

In some cases, one student becomes infected with the Influenza virus, but the student dies or recovers before the virus can spread to the rest of the population. Logically, this outcome is possible because the Influenza virus must come in contact with several people that become infected with Influenza for an epidemic to begin. The population stays at a stable number after the Influenza virus has departed from the population and is no longer affecting the model.

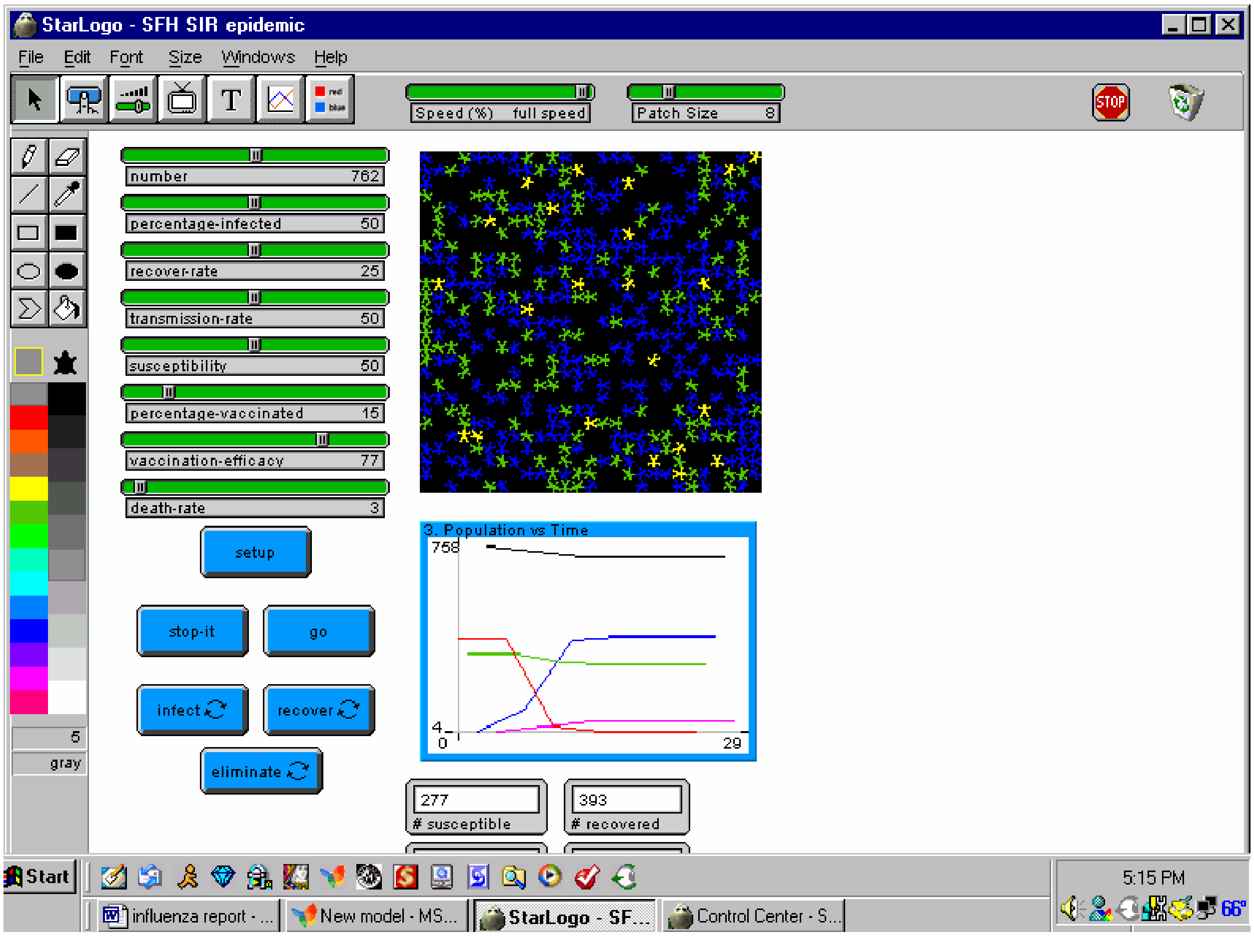


In most cases, as above, one student develops Influenza and spreads it to several other students. The total number of students, the number of sick students, and the number of healthy students decrease. The death rate and recovery rate increase and then become constant. In this case, around fifty percent of the student population becomes infected with Influenza. The infected students quickly recover, which makes the recovery rate increase. The number of healthy students decreases because over half of the student population is either sick or recovering, which means they are no longer considered "healthy." The total number of students decreases because, on average, one person dies a day from complications with Influenza. Usually the number of sick students decreases to only a few students who have Influenza. The infection rate does not increase consistently because most students have recovered from the Influenza virus and have developed antibodies to the certain strain of Influenza that spread in their population.



When the number of susceptible students in the population is decreased by 0.2%, as above, the same results occur as the case stated above. The population reacts to the Influenza virus in the same way as the case before because the transmission rate was kept at 50%, just as before. Each member of the population has the same probability of obtaining the Influenza virus, even if the number of susceptible students decreases.

The transmission rate is the most important factor in the model because it determines how fast the Influenza will spread in the population and how effectively the Influenza virus will spread from student to student. The transmission rate also establishes the probability of a student becoming infected with Influenza. If the transmission rate is increased, the total number of students decreases faster than the more common situations and the death rate increase severely.



When the recovery rate is increased from 3% to 25%, as above, the population is hardly affected by the Influenza virus because the virus dies out very quickly. Every student that becomes infected quickly recovers, and the number of healthy students stays fairly constant and elevated. A large number of the susceptible students do not become sick either. The reasoning in this case is logical because if the recovery rate is set to a high number, than the probability of a student becoming sick decreases a great amount.

The result we did not expect, before we began this project, is that the numbers of healthy and sick students decrease, as the numbers of dead and recovered students increase. The healthy number of students decreases in many different situations because almost half the student population is sick, recovering, or dead. The sick students quickly become recovered, making the number of sick students decrease significantly. Consequently, the number of dead students increases, as the number of sick students decreases, because certain students die faster, in time of days, than students become infected and show symptoms of the Influenza virus.

6 Conclusion

Influenza spreads in many ways. The Influenza virus can spread through direct and indirect contact between humans and animals. The best way to analyze the epidemiology of the Influenza virus is to understand who is susceptible to Influenza and what occurs after a person is infected with the virus. Although there are limitations to our study, we can determine the most accurate methods of controlling the spread of influenza and preventing an epidemic.

The results of our study differ greatly from what we expected. We anticipated to find that the correct technique to control influenza in a student population is to vaccinate a certain number or group of students at Santa Fe High School. We assumed that if we vaccinated as many students as possible, fewer students would obtain Influenza. Also, we presumed that, if there were a limited supply of vaccinations, it would be best to vaccinate the susceptible students prior to the rest of the student population. Our results, however, proved that our hypothesis was inaccurate, and that other factors should be considered.

Given the results of our study, we concluded that vaccinating the susceptible students does not decrease the number of students in the population who are infected with the Influenza virus. We also found that students die during their recovery process, not when students are initially infected with Influenza. We found that controlling the transmission rate and the recovery rate will produce better results. Less students are infected with Influenza if the transmission rate and the recovery rate are controlled, rather than organizing the vaccination rate and who is vaccinated. The death rate was one person per day, as expected, when the transmission rate was lower and the recovery rate was higher. When all the susceptible students were vaccinated, the death rate was higher than one person per day, and the virus's spread became unmanageable.

After viewing the behavior of the model and its graphs, we focused on the transmission rate, and how it affected other rates on the model, such as the death rate and the recovery rate. Our analysis of the transmission rate and its affect on other rates allowed us to answer our main question: what is the most precise way to control the spread of Influenza? The most precise way is treating the patients in the process of recovery and educating people about Influenza. Patients who are in the process of recovering should be the focus and should receive adequate care and assistance. The recovery process is crucial because a patient is still contagious and may die during this time. From our model, we discovered that, although vaccinating the student population is essential, health departments should be more aware of how to slow down the transmission rate of the Influenza virus, and should focus more on the recovery phase of a patient considerably.

We must, however, take into consideration that our model did not adequately portray an existing population, in which the Influenza virus erupts. The different age groups, the people who commute in and out of the city, and the transmission of the Influenza virus between animals and humans were not considered in our model. These factors, if incorporated in the model, could greatly alter the outcome of the model and possibly prove our hypothesis to be true.

7 References

Center for Disease Control and Prevention. (November 10, 2004). Key Facts About the Flu: How to Prevent the Flu and What To Do If You Get Sick. Retrieved December 2004 from the World Wide Web: http://www.cdc.gov/flu/keyfacts.htm

Center for Disease Control and Prevention. (November 2004 to March 2005). **Flu Activity** Reports & Surveillance Methods in the United States. Retrieved November 2004 to March 2005 from the World Wide Web: http://www.cdc.gov/flu/weekly/fluactivity.htm

Center for Disease Control and Prevention. (November 15, 2004). Questions & Answers: The Disease. Retrieved December 2004 from the World Wide Web: http://www.cdc.gov/flu/about/qa/disease.htm

Center for Disease Control and Prevention. (November 2, 2004). Questions & Answers: Flu Vaccine. Retrieved December 2004 from the World Wide Web: http://www.cdc.gov/flu/about/qa/fluvaccine.htm

Center for Disease Control and Prevention. (January 27, 2005). Key Facts About Flu Vaccine. Retrieved February 2005 from the World Wide Web: http://www.cdc.gov/flu/protect/keyfacts.htm

Center for Disease Control and Prevention. (September 3, 2004). Questions & Answers: 2003-04 Flu Season. Retrieved December 2004 from the World Wide Web: http://www.cdc.gov/flu/about/qa/0304season.htm

National Foundation for Infectious Diseases. (2005). Facts about Influenza. Retrieved in January 2005 from the World Wide Web: http://www.nfid.org/library/influenza/what/index.html

Washington State Department of Health. (February 3, 2005). Influenza Update 2004-2005. Retrieved in February 2005 from the World Wide Web: A:\WA State Dept of Health - Influenza Update.htm

8 Acknowledgements

Our project is the result of hard work and dedication. Atty Mullins, our mentor, helped us very much and guided us along each step. This project was made possible with Atty's commitment, patience, and kindness. Thank you Atty. We must also thank Mrs. Gerlach for her encouragement and support.

A Appendix A: Code

A.1 Turtle Procedures

```
turtles-own [sick? recovered? vaccinated?]

to infect
  rt random 100
  lt random 100
  fd 1
  if sick?      ;if you're sick, make all the other turtles on your patch sick
    [  grab one-of-turtles-here
       [
       if ((recovered?-of partner) != true)
          [if (random 100) < transmission-rate
            [ifelse vaccinated? [if ((random 100) > vaccination-efficacy) or ((random 100) <
susceptibility) [set sick?-at 0 0 true
            make-sick]]
                          [if ((random 100) < susceptibility) [set sick?-at 0 0 true
             make-sick]]]]
       ]
    ]
end

to recover
  if sick?
    [if (random 100) < recover-rate      ;randomly recover based on the recover-rate slider
      [setsick? false
       make-recovered]]
end
```

```
to eliminate
 if sick?
  [if (random 100) < death-rate [die]]
end

to make-recovered
   set recovered? true
   setc blue
end

to make-healthy
  setc green
end

to make-sick
  setc red
end

to make-vacciated
  setc yellow
  set vaccinated? true
end
```

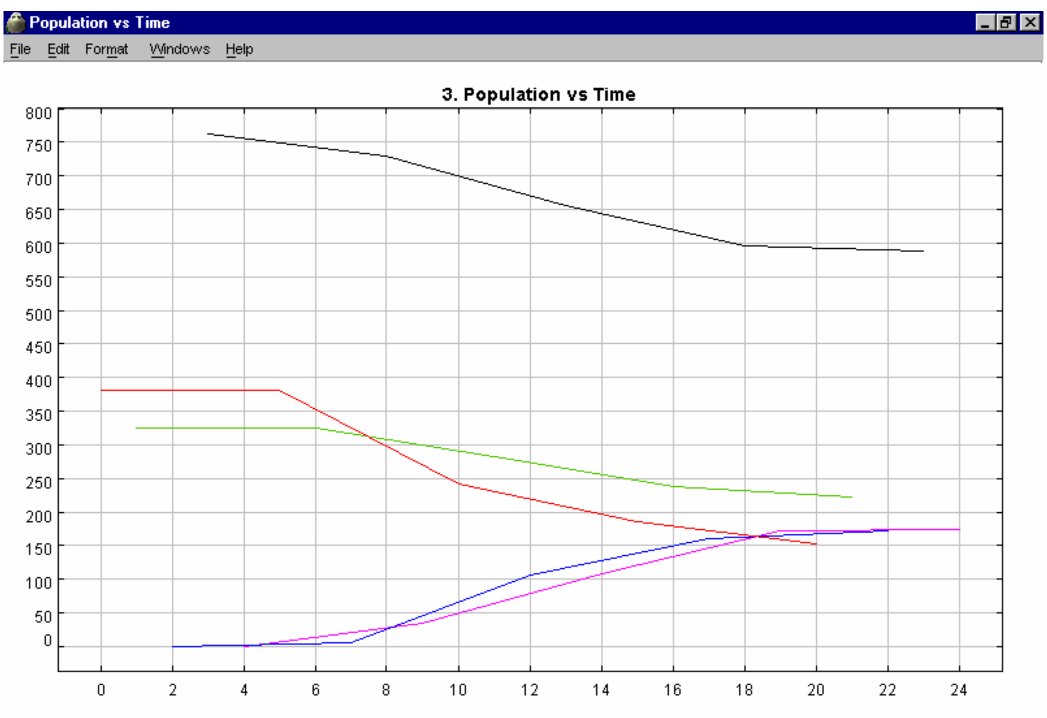
A.2 Observer Procedures

```
globals [total-infected total-vaccinated]

to setup
  ca
  crt number
  set total-infected (number * (percentage-infected / 100))
  set total-vaccinated ((number - total-infected) * (percentage-vaccinated / 100)) + total-infected
  ask-turtles
    [setxy random screen-width random screen-height
     setshape 2
     ifelse who < total-infected
       [make-sick
       setsick? true]
       [make-healthy
       setsick? false]]
  ask-turtles [if (who > total-infected) and (who < total-vaccinated) [make-vacciated]]
  clearplots
end

to go
```

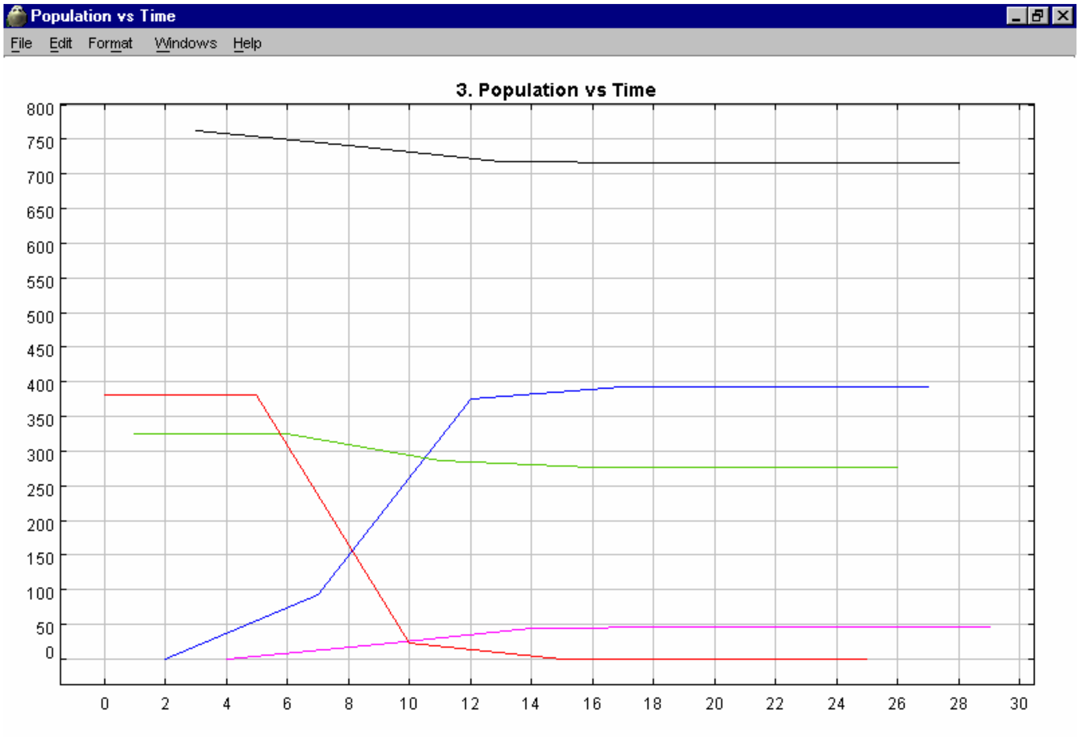
```
  startinfectbutton
  startrecoverbutton
  starteliminatebutton
end

to stop-it
  stopinfectbutton
  stoprecoverbutton
  stopeliminatebutton
end

to infected-%
  output ((count-turtles-with [sick?]) / count-turtles) * 100
end
```

B Appendix B: Graphs

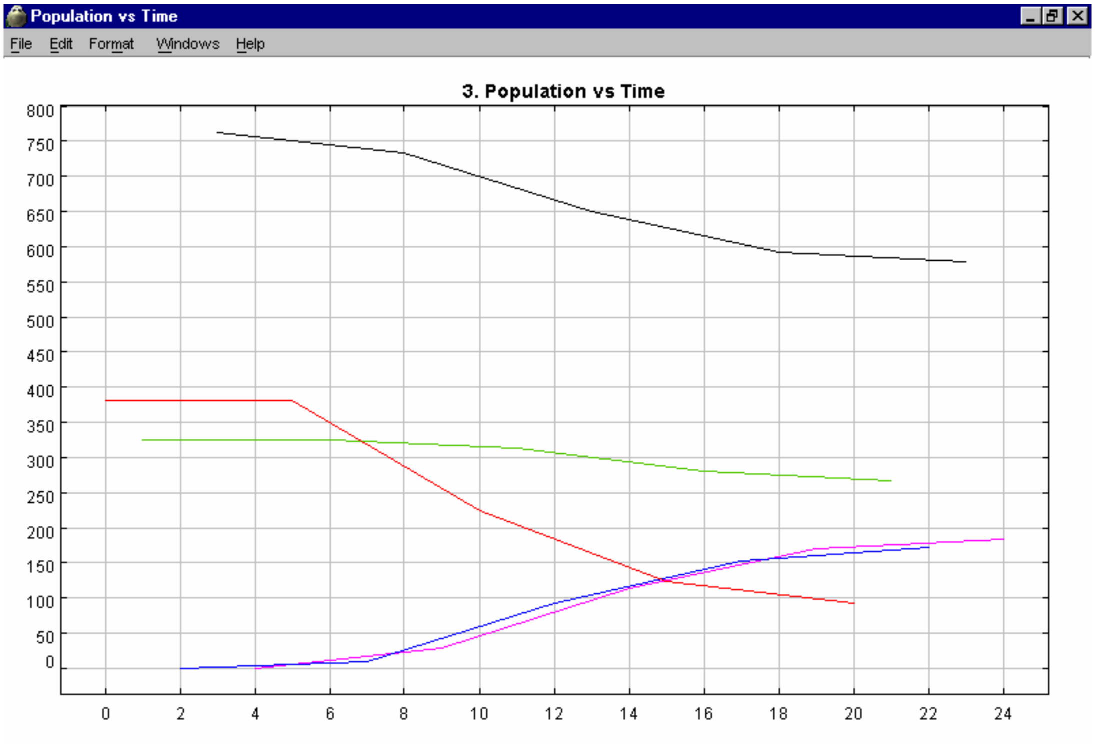
Key for graphs:
Black: total
Green: healthy
Red: sick
Blue: recovered
Purple: dead



This graph represents the model under all set conditions.



This graph represents the model when the recovery rate is increased from 3% to 25%.



This graph represents the model when the number of susceptible students is decreased by 0.2%