Herd Immunity and You

An **Interactive Qualifying Project Report**

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By:

Andrew Holmes (Mathematical Sciences)

Jocelyn Pitman (Physics/Mathematical Sciences)

Brenna Pugliese (Biology/Pre-Veterinary)

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Advisor: Jill Rulfs

TABLE OF CONTENTS

INTRODUCTION

As students at WPI we understand the importance of attending classes and meeting deadlines. For this reason it is exceedingly important that members of the WPI community take all possible measures to avoid contracting illnesses. The members of our IQP team observed a marked incidence of seasonal flu cases on campus, and thus identified a need for flu prevention education. One of the most effective methods of providing immunity to a population is the achievement of herd immunity against a particular pathogen.

We decided to take a novel approach to educating the student body by designing and implementing an interactive simulation of herd immunity. Our group constructed the following project question: Is it possible to design and execute a public health education program about herd immunity on the WPI campus? Our goal was to raise awareness about the importance of the seasonal flu vaccine with the potential aim of changing the attitudes of students that do not receive the immunization each year. Furthermore, this educational initiative was designed to dispel many misconceptions about flu vaccination. Most importantly, we endeavored to use mathematical modeling to accurately simulate herd immunity and its effects on flu transmission rates.

Influenza Virus Transmission

Acquisition of the influenza virus results in acute respiratory infection, with cases of the illness ranging from mild to severe; in very rare and extreme cases such an infection can lead to death. The flu has several means of transmission. It is important to note that it can only be transmitted via human hosts (person-to-person); no animal can spread the seasonal flu. Most commonly, influenza is spread through the coughing and/or sneezing of infected people. In addition, it is possible to contract the flu by touching an object contaminated with flu virus(es) and then touching one's nose or mouth. Those who have been recently vaccinated should still use precaution when in contact with infected individuals and/or potentially contaminated objects. These individuals are still in danger of contracting the flu, as antibodies that protect against influenza virus infection do not develop until about two weeks after vaccination (Centers for Disease Control and Prevention, 2009).

The transmission paths of the flu virus are especially dangerous on a college campus because many students are in close contact and sharing materials throughout the day. Seasonal flu can be transmitted a full twenty four hours before an infected college-aged person shows symptoms, and that person can continue to be contagious for a full week after manifesting symptoms. Rarely, an individual can even contract the flu virus and not become ill. In this case, that person can still transmit the virus for eight days while others are unaware that they could be contracting the illness. The influenza virus can also be spread person-to-person across a distance of six feet, meaning that the virus will spread incredibly quickly in highly populated areas, such as any of the buildings on the WPI campus. Symptoms of the seasonal flu can last up to a week. With terms only seven weeks long, WPI students simply can't afford to contract this illness (Centers for Disease Control and Prevention, 2011).

THE SEASONAL FLU VACCINE

The leading method of prevention to avoid contracting the seasonal flu is immunization with an annual vaccine. Studies have shown that a flu vaccine can reduce the number of illnesses with symptoms like the flu (influenza-like illnesses or ILIs) by up to 25%, and can reduce the number of days of class missed due to illness by 1/3. Still, schools see vaccination rates as low as 30.2%, well below the percentage needed to achieve herd immunity (Nichol, D'Heilly, and Ehlinger; 2008).

While many individuals receive the seasonal flu vaccine, few may understand the mechanism of action by which vaccination prevents them from contracting the illness. A vaccine's purpose is to prepare the body to fight sickness. It contains either a dead or a weakened (attenuated) virus or, more recently, a recombinant protein normally present on the viral surface that causes a particular disease. After receiving the vaccine, the body practices fighting the disease by making antibodies that subsequently recognize the specific pathogen. This process leads to immunity towards that particular illness. Therefore, if the person is exposed to the pathogen, the person will not become sick.

A common misconception is that immunizations will give someone the very disease that the vaccines are supposed to prevent. However, it is *impossible* to contract the disease from any vaccine made with dead (killed) bacteria or viruses (Kidshealth, 2009). Many patients report feeling under the weather following a flu immunization, but this is merely a part of your body's immune response. Because the body is actively synthesizing antibodies to the virus, flu-like symptoms are commonly reported. It is important to note, however, that this is not actually the flu and is generally a much milder illness than a full-blown influenza infection. Another common misconception associated with vaccines in general is that they can give you autism. Numerous studies have been performed, however, finding absolutely no link between the flu vaccine and autism (Centers for Disease Control and Prevention, 2010).

Less commonly known is the chance of contracting Guillain-Barré Syndrome, from the flu vaccine. Although you can contract this illness from the vaccine, many people believe that it is likely, not just possible. This is not the case. Numerous studies have examined the possible link between Guillain-Barré Syndrome and the seasonal flu vaccine, finding an incidence of only about 1 in 1,000,000, meaning that it is highly unlikely that someone who gets the seasonal flu vaccine will contract Guillain-Barré Syndrome. It is much more likely that an individual will contract the seasonal flu, and thus the benefits to an individual and their community of receiving the vaccine far outweigh the risks (Centers for Disease Control and Prevention, 2009).

There are multiple groups of people who should get vaccinated against the seasonal flu. In the WPI student population, the largest group which needs to be vaccinated is all teenagers. Other groups of people also represented in the WPI community who should particularly receive a vaccine include pregnant women, people 50 years of age and older, and people of any age with chronic medical conditions. In addition to the aforementioned types of people, those who live in nursing homes and long-term care facilities require vaccination. Communal living situations such as nursing homes and long-term care facilities are very similar to that of a college dormitory in that they are close-proximity living situations. Students share bedrooms, study spaces, and bathrooms, all areas in which the virus is easily transmittable. Furthermore, the target population of our educational simulation is freshmen students, which in general fall within the age range of individuals that should be vaccinated.

On average, annually in the United States, 5% to 20% of the population contracts the seasonal flu. More than 200,000 people are hospitalized from flu-related complication while approximately 36,000 deaths result from flu-related causes. The dangers of the flu are evident in the United States and vaccinations are important for protecting the health of the population

(Gardner). Thus, it is evident that due to the inherent risk of living on a college campus during flu season, an initiative should be taken to inform students of the dangers of flu virus transmission and the importance of receiving the annual vaccine.

Herd Immunity

Herd immunity is an effective means of preventing the transmission of influenza. By vaccinating a population in order to provide additional protection to the unvaccinated, herd immunity is achieved. With herd immunity, it becomes more difficult for a contagion to maintain its chain of infection (i.e. transmission rate decreases). Following this immunization practice may eventually lead to the eradication of a disease. As the number of vaccinated people increases, the likelihood that a susceptible person will either come into contact with an infected individual or contract influenza decreases significantly. If a significant portion of a population becomes immunized, a disease may eventually cease to exist, as demonstrated by the eradication of smallpox as a result of global mass vaccination (Gardner, 2009). In order for this method to yield positive results for reducing transmission of the influenza virus, approximately 75% to 80% of a population must become immunized. With these percentages, the virus will have difficulty reaching the unvaccinated, thereby preventing person to person transmission and lowering the infection rate in the population.

Herd immunity is an extremely viable option for reducing the spread of disease to the unimmunized, but a small percentage of a population can be left unvaccinated. This portion is generally reserved for those who cannot safely receive the vaccine due to an underlying issue such as a medical condition. People with chronic immune deficiencies or those waiting for organ transplants are unable to receive the influenza vaccine, and therefore can benefit tremendously from herd immunity. Vaccinating 75% to 80% of the general public forms a "blanket" of immunity which protects those who would otherwise be susceptible to the flu.

Mathematical Modeling of Herd Immunity

Herd immunity has become a highly discussed topic with regards to not only its biological context, but its mathematical feasibility. According to Paul E.M. Fine (1993), a mathematical biologist, "there has been a proliferation of views of what it means or even of whether it exists at all." Prior to developing the simulation for the *Herd Immunity and You* project, the mathematical roots of the model of herd immunity were explored, the true definition determined, and its existence mathematically justified.

Many researchers have based the herd immunity argument on a paper published by Fox et al. In this paper Fox used the medical definition of herd immunity: the resistance of a group to attack by a disease to which a large proportion of the members are immune, thus lessening the likelihood of a patient with a disease coming into contact with a susceptible individual (Fine, 1993). It seems clear that even this medical definition lends itself to multiple interpretations; the quantitative and the qualitative interpretations of herd immunity. The qualitative interpretation of herd immunity focuses on there only being a partial resistance, as demonstrated by the reduction in cases. Therefore, there is no mathematical theory supporting the qualitative herd immunity theory. However, using mathematical modeling techniques, a quantitative measure of herd immunity can be identified that would ensures total resistance. There is a threshold number, a percentage of the population, that must be vaccinated to stop the infection. Most herd immunity theories seem to use a combination of the qualitative and quantitative definitions of herd immunity.

There are three theories used to measure herd immunity; the mass action principle, case reduction rates and the Reed-Frost heterogeneous population simulation approach. The mass action principle uses a mathematical system of equations that measure the number of cases at different iterations of a time interval. This formula was developed in 1906 by Hamer, an epidemiologist. The expression that describes the mass action principle is: $\frac{C(t+1)}{C(t)}$ which varies with $s(t)$, which represents the number of susceptible members of the population and $c(t)$ is the number of cases of infection in a population at time, t. From the first equation, a new relation can be constructed to derive a second equation. That is, $c(t+1) = c(t)s(t)r$ where r represents the contact rate. The contact rate is a transmission parameter that is dependent on the type of infection.

Similarly to the second equation, there is an iterative equation for the number of susceptible members. The third equation is as follows:

$$s(t+1) = s(t) - c(t+1) + b(t)$$

This equation includes a new variable $b(t)$ that represents the birth rate or the number of new susceptible members added to the population. The mass action principle also goes on to construct an equation to determine the threshold for herd immunity. This fourth equation is as follows:

$$H = 1 - \frac{S(e)}{T} = 1 - \frac{1}{rT}$$

where T represents the total population size, $S(e)$ the epidemic threshold number of susceptible people and H is the herd immunity threshold, the number of immune persons needed to achieve herd immunity.

The use of case reduction rates is an analytical approach to justifying herd immunity. The theory is simple; with fewer people who can get infected there are consequently fewer people that can infect others. This is also similar to the Reed-Frost heterogeneous population simulation approach. However, the Reed-Frost method has its limitations because unlike the mass action principle, the Reed-Frost simulation only works effectively on a closed population. The Reed-Frost simulation approach is developed from a simplistic susceptible-infected-recovered (S-I-R) model.

The S-I-R model involves understanding the rate of change of the susceptible, infected, and recovered individuals in a given population. The S-I-R model can only be effectively used if the population can remain closed and unaffected by the outside populations. This model is a dynamic system of equations based on three variables: S, which represents the number of susceptible individuals in the populations; I, which represents the number of infected individuals in the population; and R, which represents the number of recovered individuals in the populations. The systems of equations are as follows:

$$\frac{dS}{dt} = m - (BI + m)S$$

$$\frac{dI}{dt} = BIS - (m + g)I$$

$$\frac{dR}{dt} = gI - mR$$

There are also three constants that only change based on the disease and the population. Firstly, there is m representing both the death and birth rate of the population. Secondly, the constant B represents the contact rate of the disease. With this model there exists an optimistic view of phrasing the effects of the disease. g represents the recovery rate which, in return, converts infected individuals to recovered individuals, instead of g representing deaths in the population (i.e. a dead individual is equivalent to a recovered individual, as they are both no longer infected) (Shulgin, Stone, Agur; 1998).

If these systems of equations are examined alongside the mass action principle system of equation there is a hint of similarity. The major difference seems to be the mathematical means of representing the equations. The mass action principle takes a linear approximation approach to modeling, while the S-I-R model uses a nonlinear model that increases the accuracy. For a linear system, accuracy is only preserved under the limitations of certain assumptions including a closed population and fixed birth and death rate. The nonlinear system expands beyond the limitation of a closed population and fixed birth and death rate, meaning that individuals may physically enter and leave the population, and births and deaths will occur dynamically. The latter model is a more accurate representation of a real population as these variables constantly fluctuate.

Each model can be demonstrated using a feasible example. Let the population equal 50 with 10 vaccinated, 3 infected, and 37 susceptible individuals. The disease has the mathematical properties that its contact rate is 0.19, recovery rate is 0.143, and on average the birth-death rate is 0.001.

The following is an example of modelling herd immunity using the mass action principle:

Start at t=0

$$c(1) = c(0)s(0)r = (3)(40)(0.19) = 22.8$$

$$S(1) = S(0) - c(1) + b(0) = (40) - (22.8) + (0.001 * 50) = 17.25$$

$$H = 1 - 1/\ (0.19)40 = 0.868421053\ i.e\ (86.84\%)$$

The mass action principle results are straightforward; over 1 unit of a time interval, the infected population increased to 22.8 and the susceptible population dropped to 17.25. The mass action principle also determined that herd immunity will occur if/when 86.84% of the population is recovered. However, we cannot see numerical patterns without going through several more iterations of this model.

The following is an example of modelling herd immunity using the S-I-R model:

$$ds/dt\ = 0.001 * 50 - ((0.19)(3) + \ 0.001 * 50))(40/50) = \ -0.456$$

$$dI/dt = (0.19)(3/50)(40/50) - (0.001 + (1/7))3 = 0.008691$$

$$\frac{dr}{dt} = \left(\frac{1}{7}\right)\left(\frac{3}{50}\right) - (0.001)\left(\frac{10}{50}\right) = \ 0.00837143.$$

In this S-I-R model the results are not as direct, but there is still an observable pattern based on each rate of change. The negative sign of $ds/dt = \ -0.456$ indicates that a decrease in the susceptible individuals can be expected over a relatively short period of time. The positive sign of $dI/dt = 0.008691$ indicates an expected increase in the number of infected individuals. Similar to the results of the model using the mass action principle, with an increase in the infected population, we expect that more individuals will become recovered over time, which can be seen through the result $dr/dt = 0.00837143$ (positive sign). Both systems of equations have benefits; however the use of one model or another is dependent upon the mathematical expertise of the user and the resources/tools at their disposal. In the modeling of the *Herd Immunity and You* simulation the S-I-R model was chosen for use, as it is more accurate in its predictions. The aforementioned equations of this model were programmed into Matlab using the percentages of infected, vaccinated, and susceptible individuals we used in our simulation population comprised of 96 individuals.

The Educational Value of Simulations

Understanding the costs and benefits of an educational simulation is necessary to building a program that will engage and effectively teach participants. Though our simulation was not based on the measures that should be taken in an emergency situation, it is similar to a disaster preparedness simulation in that we educated individuals as a prevention measure. Natural disaster preparedness prevents illnesses, deaths, and promotes timely recovery; in our project we are promoting prevention of the seasonal flu.

Disaster preparedness simulation exercises have been known to be effective educational tools by improving a community's response to natural disasters. Success of such an approach was demonstrated by the United Nations preparedness effort entitled the *Indian Ocean Tsunami Warning System*. This effort was designed to enable "more effective governmental response" to future disaster scenarios following the December 26, 2004 tsunami that devastated Sri Lanka. The US Forest Service began delivering Incident Command System (ICS) training, and worked with the Sri Lankan government to develop a full scale simulation of a disaster scenario to test management plans and team skills (USDA Forest Service Northeastern Area, 2011).

With a soccer field designated as the Incident Command Post, the local Sri Lankan police force, fire and emergency services, public works department, environmental spill responders, electric power utility employees, and the Red Cross came together to run a large scale simulation. Prior to the commencement of the simulation each group underwent ICS training to help enable a managed team response and develop disaster response plans. The three and a half hour disaster simulation involved twenty five replicated disaster inputs. Such exercises simulated mass casualties, interruption of electronic communication, civilian medical and fire emergencies, environmental impacts, and civilian evacuations (USDA Forest Service Northeastern Area, 2011). It should be noted that several agencies and an immense amount of sheer man-power were required to make this simulation a successful endeavor. Furthermore, adequate training of the involved groups was administered prior to the start of the simulation.

This program not only served to educate those involved with a disaster response, but it also served to test individuals in their understanding of the administered ICS training. Furthermore, this educational simulation identified areas to improve the local disaster management response plans that were currently in place. The tsunami of December 2004 devastated 75% of the coastal belt of Sri Lanka, causing 3,800 deaths and displacing 44,500 people in the Southeast Asian area. These statistics evidenced the need for action in the form of providing education, organization, and an infrastructure to those involved in taking action during a natural disaster (i.e. police, medical personnel, etc.) "Hands on" learning in the field is an educational tool that forces participants to be actively involved, using all of their senses to gather and truly understand the information being presented to them. Physical participation is a true test of understanding (USDA Forest Service Northeastern Area, 2011).

Though disaster simulations such as the aforementioned exercise in Sri Lanka are viewed as the traditional method of testing disaster plans, there is little scientific data evidencing their benefits. Running an educational simulation can often be costly, time consuming, and use many resources. This lack of data prompted researchers in Australia to conduct a study in which 50 members of a medical team participated in a disaster preparedness simulation in a Geelong hospital; the exercise was preceded by a survey that "tested factual knowledge as well as perceptions about individual and departmental preparedness." Following the "intervention," the group was again anonymously surveyed. This survey was identical to the first, but also included additional questions regarding the individuals' involvement in the exercise. The goal of the study was to determine if an educational simulation indeed improved "staff knowledge, confidence, and hospital preparedness for disasters" (Walsh, Stella, Bartley; 2006). This style of research is precisely the approach that *Herd Immunity and You* took in conducting the survey and simulation. Anonymity was preserved and pre- and post- questions were posed to the participants to evaluate the extent to which the herd immunity simulation was successful in educating WPI students.

Prior to running the disaster simulation in the Geelong hospital, the researchers engaged in informal discussions with the medical and nursing staff. Their general impression was that there was limited knowledge of the hospital disaster plan among these groups of people, and that disaster preparedness was a low priority. This was extremely alarming, as the previous statement held true in the intensive care unit and operative services department. The simulated mass-casualty exercise involved delivering 45 patients to the Geelong Emergency Department. Each of these patients "underwent real time triage and registration followed by compressed time treatment and disposition." The exercise also included several lectures and an audiovisual presentation of the hospital's disaster plan (Walsh, Stella, and Bartley; 2008).

An anonymous survey played the central role in the determining the extent to which this disaster simulation was successful in educating the medical personnel. Not only did the pre and post surveys test factual information of the hospital's current disaster plan, but also allowed self-assessment by the participants in which they evaluated personal and departmental disaster preparedness. It is this element of self-assessment that was essential to the survey developed for *Herd Immunity and You*. It is important that the evaluators had knowledge of the students' attitudes and opinions regarding vaccination, as well as their current understanding of herd immunity prior to the simulation. This allowed a comparison to be made between the statistics pre-simulation and post-simulation, and helped to determine the "success" of the simulation in educating the participants.

This research study stressed the importance of providing concrete statistics to support the claim that educational simulations (in this case in disaster preparedness) are indeed beneficial. The pass rate (a passing grade was agreed to be a 70% by the Geelong ED Disaster Committee) was 18% on the pre-intervention factual survey. The pass rate of the post-intervention survey showed a statistically significant increase at 50%. The mean score on the pre-intervention survey for the emergency department staff members was 12.1/20. The post-intervention score for the same group of individuals was 15.8 following completion of the simulation. A perfect score was only achieved by one person on the pre-survey, while five individuals achieved perfect scores on the post-survey (all of which were Emergency Department staff members). With regards to the self-assessment portion of the evaluation, prior to the simulation, 32% of the participants responded "disagree" to the statement "I am personally prepared [for a disaster situation in my department]. Following the simulation the most common response to the same statement was "agree," at 42.5%. The majority of individuals (53.7%) described the disaster preparedness exercise as a benefit to themselves, and 63.2% felt that it was also beneficial to their department (Walsh, Stella, and Bartley; 2006).

The statistical results of this research support the current belief that simulation is a beneficial and effective learning tool. However, it was determined that those involved directly with the simulation (i.e. the disaster exercise and the educational process) experienced the greatest benefit, as individuals and departments as a whole. Thus, here it is evidenced that encouraging participants to become actively involved in a simulation yields the best results when aiming to educate a group of individuals.

The researchers found that a problem exists when deciding if the benefits indeed outweigh the costs of running a simulation. "It is difficult to determine how much time, money, and effort should be spent on preparing for an event that may never occur" (Walsh, Stella, and Bartley; 2006). This may be true in regards to a disaster scenario such as a terrorist attack or a natural disaster; however, there is a case to be made here regarding our project *Herd Immunity and You*.

One of the largest simulations designed in the public health field was constructed by a group of scientists at New York University. The Large Scale Emergency Readiness (LaSER) project at NYU's Center for Catastrophe Preparedness and Response (CCPR) used computer simulation to "assist hospitals and cities in preparing for worst-case scenarios" (healthnewswire.net, 2009). The program, called Plan C, approaches worst-case scenarios by using simulation techniques with multiple variables that include information about the demographics in a city, resources at local hospitals, and traffic volumes in the public transit system. Dr. Silas Smith of NYU's School of medicine used Plan C to simulate a release of sarin simultaneously in various locations of Manhattan. Sarin is "one of the most toxic of the known chemical warfare agents" (NIOSH, 2008). Sarin could be introduced into a population in a number of different ways: it can be released in to the air, both indoors and outside, in an aerosol or vapor form; can contaminate water; can contaminate food; and has the potential to contaminate agricultural products, such as farm-grown vegetables, if it is released as an aerosol near a farm. These properties are what made sarin such an excellent model infectious agent in the simulation.

Factoring in the nature of the geographic area (Manhattan) and the nature of the agent being released (sarin toxin), Plan C can accurately predict how area hospitals will be able to handle the influx of patients, and determine how emergency response teams can best organize themselves in order to minimize the effects of the toxin release. This information is especially important for emergency teams to have ahead of time in order for them to plan, but knowledge of what resources would be necessary could also help emergency workers garner the necessary funding. It can be incredibly difficult to convince administrative teams that a certain amount of funding is necessary, and having a simulation to show exactly how a certain amount of funding would be used and is necessary is much more convincing than an estimate based on what scientists *think* will happen (Agency for Healthcare Research and Quality, 2008). Our simulation provided similar concrete evidence illustrating the benefits of investing in a flu vaccine each year.

Plan C established a fairly strong precedent for the effectiveness of simulations of healthcare issues. Sarin toxin can cause much more damage when released into a population than the influenza virus can, but if a simulation can accurately represent a disaster of that scope, it can certainly help us determine information about the spread of influenza. Although our simulation did not take into account as many variables as the Plan C simulation, by examining our situation on the WPI campus we determined that we didn't need a simulation of that scope. First, our campus doesn't have as many people as Manhattan, especially since we're only aiming to educate the student population. Also, our campus is much more "closed" than Manhattan is; we do not have a public transportation system moving tens of thousands of people in and out each day. We can also idealize influenza transmission rates with the knowledge that WPI students are in near-constant contact with each other. Between passing each other in academic buildings, hanging out in the campus center for club meetings or activities, and living in or visiting the residence halls on campus, it's not hard to see how any communicable disease can disseminate incredibly quickly through the campus population.

Undergraduate Public Health Education

The lack of education about herd immunity in today's society often leads to the spread of false information throughout the media. This dispersion of inaccurate educational materials across the internet is dangerous; many college students turn to the web for healthcare advice, not investigating the validity of the source they are trusting. With the freedom for individuals to publish work online, it is not uncommon to find ambiguous and misleading facts about vaccination on the internet.

The website entitled *Natural Health Remedies & Strategies for Healthy Living* is a prime example of such a site that presents visitors with unqualified and often out of context information. The site, aimed towards protecting individuals from the dangers of modern medicine, has a page dedicated to deterring individuals from vaccination. Here the unknown author briefly lists approximately twenty historical events that supposedly expose the truth about the ineffectiveness of immunization. For example one claim reads, "In 1978, a survey of 30 States in the US revealed that more than half of the children who contracted measles had been adequately vaccinated" (Natural Health Remedies & Strategies for Healthy Living, 2010). This information may in fact be true, but it is taken entirely out of context. There is no mention of the actual number of cases that the author is referring to. It is very possible that the number of infections is dwarfed by the number of cases of infection in children that existed prior to vaccination for measles. It is certainly possible that "more than half" of the infected children (whatever that number may be) is still a much smaller number of cases of infection than the number of cases that could occur during an epidemic in which the population was not vaccinated at all. Thus, the lack of comparison between the number of cases of infection in 1978 and before the time of immunization makes this statement exceedingly misleading. Furthermore, the majority of the "historical events" that are mentioned on this page are from the mid 1900's. Thus, they do not take into account the advances in modern medicine since that time. Medicine in 2011, the 21st century, is much different than medicine in the 20th century (Natural Health Remedies & Strategies for Healthy Living, 2010).

One of the most notable points of this website is that there is no mention of herd immunity. Each "fact" that speaks against vaccination never looks deeper than the individuals being vaccinated; it is important to understand the repercussions of immunization against any disease. The power of herd immunity is its ability to slow the rate of infection by creating a safeguard for those who cannot be vaccinated. No educated literature will express that vaccination or subsequent herd immunity will protect everyone, even those who are vaccinated. However, those with a chronic illness or allergy to a particular vaccination increase their likelihood of avoiding infection when they are in a population of those who are immune. The author of this site does not make such an acknowledgement, nor do they attempt to make an all-encompassing argument to support their claims.

Herein lies an illustration of the need for our project. The average college student often does not think of others when deciding whether to get a seasonal flu vaccine. Many students do not consider how easily they could, once they contract the virus, spread it to someone else. There is an apparent lack of knowledge among WPI students about herd immunity and how important it is to achieve herd immunity in a population that is so closely interconnected. By running our simulation and educating students about how they can help others not get sick by vaccinating themselves, we aimed to encourage students to increase the vaccination on campus and dispel certain myths about flu vaccines that have become popular in recent years.

Following identification of such a need in our campus community, a logical approach would be to develop a novel form of public health education to address the issue of herd immunity (or lack thereof). It is important that students become aware of their peers and their health, and the ways that we can create a healthier community through a basic understanding of epidemiology. A concept as simple as educating a group of WPI students about the importance of herd immunity could induce a social change in the population. Such an initiative is not a common occurrence amongst undergraduate universities; however, this does not diminish its importance.

In 2003, the Institute of Medicine made a forward thinking proposition with regards to undergraduate education. Its report *Who Will Keep the Public Healthy? Educating Public Health Professionals for the 21st Century* recommended that "undergraduates should have access to education in public health" (Riegelman, 2008). This statement was made on the basis that providing knowledge of public health is "an essential part of the training of citizens" (Riegelman, 2008). Today, the popular media is constantly flooding individuals with medical and scientific studies containing highly pertinent information to the members of our society. This valuable research can easily be "misunderstood and misapplied by the uneducated reader," and often this lack of education can lead to dangerous preconceived and widespread notions about health and science (Marantz, 2008). The ability to correctly interpret such principles, especially those relating to epidemiology, can lead to an overall healthier society. However, widespread knowledge cannot be attained without programs in public health.

Molding informed citizens should be a top priority of undergraduate institutions. Currently, courses in public health and epidemiology are reserved for those studying at the graduate level. There is an existing "instinctive rejection" of the idea of offering such courses to undergraduate students (Marantz, 2008). Such courses are often taught by those who had their start in the discipline as a graduate student; thus, there are many biases with regards to how they were educated. This type of preconception is acting as a barrier to providing students with an education in public health at the undergraduate level.

The Institute of Medicine has acknowledged that this area of education has been overlooked at the undergraduate level in the past. Moving into the future however, such programs that would provide students with an education in public health and epidemiology should not be “viewed as a professional credential but as a part of the preparation of educated citizens regardless of their future career direction” (Riegelman, 2008). It was our IQP team’s hope to bring such an element of public health education to WPI by developing a simulation of herd immunity- with the goal of increasing awareness of the importance of vaccination against the flu to the health of our school’s community as a whole.

Learning through theory and practice has been a long-standing tradition at WPI. This mode of education is closely linked to experiential learning, an approach undertaken by students who are afforded the opportunity to not only acquire knowledge, but to learn in an “immediate and relevant setting” (Cashman and Seifer, 2008). Experiential learning goes beyond the traditional trappings of a classroom setting. It involves a “direct encounter with the phenomena being studied rather than merely thinking about the encounter, our considering the possibility of doing something about it” (Cashman and Seifer, 2008). Instead, students are active participants in the process of learning and are involved in a way that engages them to analyze their learning environment, actions, benefits, and consequences. Such an experience is an important tool in learning; being immersed (physically and mentally) in an activity allows for students to make their own discoveries. More powerfully, students can reflect on their experience and develop new ways of thinking about the topic at hand. The desired outcome of our simulation was to develop new attitudes among student participants, to induce a consciousness of public health, and to encourage them to promote beneficial health measures among their peers, specifically, getting vaccinated against the flu. This ideal result would not only demonstrate the importance of the seasonal flu vaccine to the health of our community, but it would represent an effort of public health education at WPI.

MATERIALS AND METHODS

There were two main components to consider during the construction of our project: the public health education program and the simulation of herd immunity. To preserve the anonymity of the subjects, the mode of data collection was a series of online surveys. In coupling these two aspects of our project, proper materials had to be determined to provide the most effective form of education.

We selected a specific group of students, the incoming freshmen who would live on the third floor of the Morgan residence hall starting with new student orientation on August 21, 2011. This population consisted of 96 persons, 66 males and 30 females, and was ideal because the Morgan residence hall is centrally located and this male-to-female ratio accurately represents the overall WPI student body. The choice of this population eliminated any chance of gender bias that we may have encountered had we chosen to run the program on an all-male or all-female residence floor.

The first step in our program was to administer a completely anonymous preliminary survey in order to gather data about the population that would be participating in the simulation. At this stage we asked students if they would be willing to participate in the simulation in order to estimate the number of participants and give students the option to opt out of the program during new student orientation (NSO) in order to eliminate any chance of perceived coercion affecting the outcome of the study. This preliminary survey was administered via email over the summer, after students had received their housing assignments but before they arrived on campus. The questions for this preliminary survey appear in appendix 1. The main purpose of this survey was to try to identify how many people in the population get a seasonal flu vaccine in a given year and reasons why those who choose not to get a vaccine do not. This information was important for two reasons: if people choose not to get vaccinated because of misinformation about vaccine dangers then we would need to educate them about the facts; if people do not get a vaccine because of religious concerns or an immune deficiency, then it may help to tell others in the community that there are students with these concerns in order to encourage those who are able to get vaccinated so they can protect those who are unable to get vaccinated. Education about vaccinations in the population is the best way to indirectly achieve herd immunity, since we can't force people to get a vaccination involuntarily. We designed the other questions in our survey around these main ideas, but each question had a specific purpose and added in a very important way to our project.

Question 1 of our preliminary survey asked how many students had ever been diagnosed with the seasonal flu. Our intention was to establish how many individuals in our population had been personally affected by this virus, which helped us to tailor the educational portion of our project. In discovering how many people had had the flu, we were able to determine to what degree the students needed to be educated about the seasonal flu, its transmission mechanisms, and the misconceptions associated with the virus and the vaccine alike. With question 2 of our preliminary survey, we aimed to determine the current vaccination rate within the population by asking how many students try to get a flu vaccine each year. Knowing what percentage of the student body currently gets a vaccination told us whether there was a demonstrated need for our project. Because vaccination rates need to be around 80% in order to achieve herd immunity, if the survey showed that less than 80% of the student body gets a vaccination each year, we would see a need for our project. The information about how many people we needed to "convince" to get a vaccine helped us, along with the data from question 1, figure out the extent to which we needed to educate the students.

Question 3 of our preliminary survey asked whether students intended to get the seasonal flu vaccine this year (fall 2011). We asked this question to establish a baseline to which we could compare the responses from the post-simulation survey. Question 3 of this post-survey was essentially the same as in the preliminary survey. In this way, we would be able to see exactly how many minds our project changed and what effect we may have had on establishing herd immunity within our population.

In our endeavor to gather data about why students do not get vaccinated, we asked a multiple choice which listed a plethora of legitimate and illegitimate reasons to avoid the flu vaccine. This is where the misconception education portion of our project comes in to play. We listed as possible reasons to not get the flu vaccine both “chance of getting the flu from the vaccine” and “danger of contracting a more serious illness (autism, Guillain-Barré Syndrome, etc.).” We did this even though you cannot get the flu or autism from the vaccine, and chances of contracting Guillain-Barré Syndrome are very slim. We were aiming to see how widely believed these misconceptions were so that we could construct our educational materials around the population.

The other possibilities listed fell into two main categories: reasons why someone couldn’t get a vaccine and reasons why someone who could, didn’t. For instance, we put pre-existing immune deficiency on the list because individuals with this condition could get extremely sick from the vaccine, thus causing the risks to outweigh the benefits. Vaccine cost is also on the list, but someone who is prevented from getting the vaccine due to cost could, conceivably, get the vaccine if it were offered for free or at a reduced rate. By analyzing the responses to this question we were able to see how many minds could potentially be changed with our project. Also, by asking whether religion or immune deficiency prevented anyone from getting vaccinated, we were hoping to be able to tell the remainder of the population that they could help their peers by getting vaccinated themselves.

Questions 5 and 6 didn’t end up being all that relevant to our project. In question 5, we asked whether students would be interested in participating in the simulation in order to learn the level of interest, but during NSO most students participate in everything, so we ended up with a

100% participation rate. Question 6 asked whether students would get the flu vaccine if it was offered for free on campus. We asked this as another way to learn how many minds we could change and how we could increase the vaccination rate.

Prior to the start of the simulation, we gathered the students on Sunday, August 21, on their residence hall floor. We used this meeting time to explain what the students would be doing on the following two days and to answer questions about the procedure. On August 22, 2011 we ran the first part of our two part simulation. The simulation ran during most of the day, 10:00AM to 12:00 midnight, and was designed specifically to not interfere with the normal activities that take place during NSO. We decided to begin the simulation at 10:00AM as to avoid all of the students being on the residence hall floor together when the simulation began (i.e. they all get together to go to breakfast at 8:00am). This could potentially skew the data collected regarding transmission rates, as the lack of dispersion of participants could cause many people to become infected in a short period of time. Similarly, we made a rule that they could not "infect" each other on the third floor of Morgan at any time of day to avoid the aforementioned problem. Furthermore, we decided to end the simulation at midnight to extend the contact time of student participants, and create a more accurate representation of a typical school day. Each student was randomly assigned an "infection status," either "infected," "vaccinated," or "not vaccinated and not infected." The number of people with each status was predetermined based on plausible percentages and survey data. Ten percent of students started out as infected; this is a conservative estimate of the percentage of infected people introduced into a population during flu season. The percentage of students who started out vaccinated was based on the survey responses. This helped us to accurately represent the population involved in the simulation so that we could assure better accuracy in our results. The remainder of the students were denoted as vaccinated but not infected; therefore, they were "susceptible" to becoming "infected."

Students participating in the simulation were given an envelope the night prior to the day one simulation containing a wristband corresponding to a specific infection status. The distribution was blind (by placing random envelopes under their doors on the residence hall floor) and the names of students and their specific infection status were not recorded, so anonymity was preserved. Furthermore, the "status" of each individual was marked on the inside face of the band, and students were told not share their status with others to maintain anonymity during the simulation. Students were instructed to wear these wristbands for the entire day, and students were able to become infected and infect other people based on their status during the normal interactions of their day around the WPI campus. "Infected" students started out with sheets of stickers that were included in their envelopes. "Infection" occurred when an "infected" student placed a sticker from their sheet on a "non-vaccinated, non-infected" student. This student then became "infected" and could begin "infecting" others. The members of the IQP team remained in the wedge for the entirety of the day so the students could report to this location to get stickers once they became "infected". At the end of the day, we asked students via email to complete a simple survey, seen in appendix 3, so that we could determine how widespread the "infection" was at the beginning of the day compared to the end of the day.

Day two of the simulation was executed exactly the same as day one of the simulation, the only difference being the vaccination rate. The same materials were used, but we began with eighty percent of the population vaccinated in order to demonstrate the effectiveness of herd immunity. The procedure for infecting those students that were not vaccinated was the same, and the day started with a ten percent infection rate. The same survey was administered at the end of the day in order to determine how many people became newly infected.

On the third day, we intended to present our findings to the students involved in the simulation. During this time we planned to hold an informational talk about the realities of the seasonal flu vaccine and the importance of herd immunity. There was also going to be a question-and-answer session following the informal talk, encouraging students to bring up points they were confused about or things they wanted to know more about. We also intended to distribute our findings and links to informative websites via email to the participants following this discussion, should they wish to continue their research. Unfortunately, despite repeated email notifications of the meeting location and time, none of the student participants attended this talk. As a result, we planned a focus group for September 28th, 2011 as this would allow the students time to acclimate to student life at WPI, and hopefully increase attendance. Moreover, we decided to provide an incentive for attendance by giving $5.00 Dunkin' Donuts gift cards to all participants, again, to encourage students to be involved in the focus group.

After the completion of this talk and the distribution of educational materials via email, we administered a final post-survey. This survey included the questions below, which are all of the questions asked in the first survey omitting the one about willingness to participate in our simulation and also including a question asking the participants if there was anything that they would have liked us to do differently. We asked this here instead of in the focus group so that students who might not want to voice their concerns in a crowd could still have a chance to be heard. In this survey, we asked both whether students had previously intended to get a flu vaccine and whether they NOW intend to get the flu vaccine this fall. This was to determine concretely how many minds we had changed with regard to getting the flu vaccine. We asked the same question about reasons for avoiding the vaccine as we had in the pre-survey. In this way we were able to determine whether we had reduced the number of students who believed the misconceptions we mentioned or who did not think, for instance, that a fear of needles was a good enough reason to not get vaccinated anymore. This post survey, found in appendix 5, was designed to help us determine the effectiveness of the project and may tell us whether we changed any minds about the flu vaccine.

RESULTS/CONCLUSIONS

On August 18th, 2011, we began our data collection process when we sent out our preliminary survey to the residents of Morgan 3. This survey was open until 4:00 PM on Sunday, August 21st, and we received 74 responses from the 96 residents. From the responses to this survey, we constructed our simulation materials to accurately reflect the makeup of the population we were studying. Figure 1 illustrates the average seasonal flu vaccination rate among the residents of Morgan 3. Because the responses illustrate a 27% vaccination rate, we prepared 26 "vaccinated" wristbands for use in the first day of the simulation. Similarly, we prepared 10 "infected" wristbands, corresponding to approximately a 10% infection rate. 63% of the population remained, corresponding to 60 "not vaccinated, not infected" students participating on day 1. It should be noted that 73% of our population responded that they *do not* generally receive the seasonal flu vaccine each year. This is effectively the opposite of the 75% to 80% vaccination rate needed for herd immunity, thus demonstrating a strong need for our project.

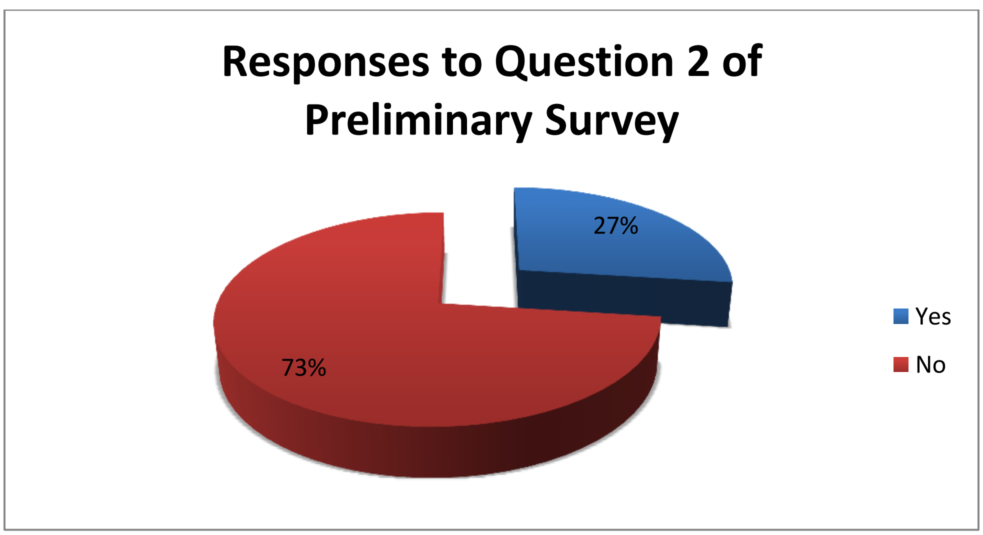
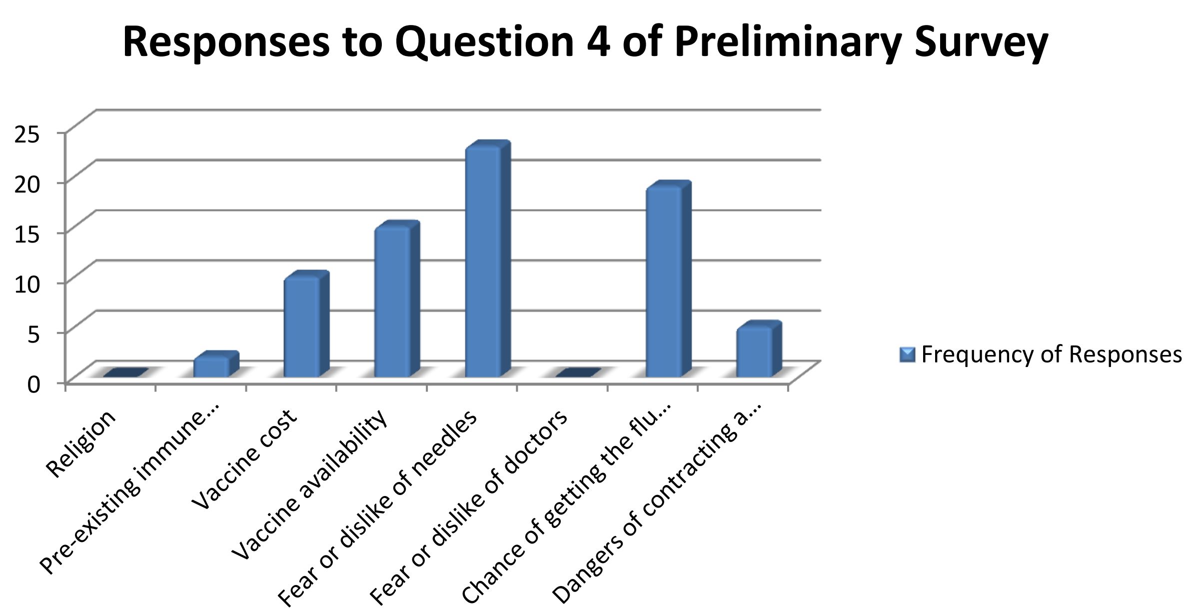


FIGURE 1: Responses to: "Do you make an effort to get the seasonal flu vaccine each year?"

In question 4 of our preliminary survey (and question 3 of our post-survey) our aim was to determine reasons why people would avoid the seasonal flu vaccine. The most commonly chosen responses were, in order, fear or dislike of needles (23), chance of getting the flu from the vaccine (19), and vaccine availability (15). Following the completion of the simulation, the most commonly chosen responses were, in order, fear or dislike of needles (12), vaccine cost (8), and vaccine availability (7). These results illustrate that we were able to educate individuals about a common misconception surrounding the seasonal flu vaccination; "chance of getting the flu from the vaccine" went from being the second most common response, to the fourth. Also, the frequency of responses for "danger of contracting a more serious illness" decreased by 80% from the preliminary survey to the post-survey (Figure 2).

Less than 10% of the participants attended our focus group in which we presented the facts about vaccination and held a discussion about the students' vaccination concerns. Therefore, we cannot be sure that all of the students read the PowerPoint containing the pertinent information that may have changed their minds about vaccination. This uncertainty may account for the response frequency not decreasing as much as it potentially could have if all participants had physically attended the educational portion of our project. Also, because our surveys were administered anonymously, we cannot guarantee that the set of respondents for the preliminary survey is the same as the set of respondents for the post-simulation survey. We still had a significant portion of the population respond both times, however, which ensures that our data and analysis are statistically valid. Furthermore, it became apparent that the primary reasons that students do not receive the vaccine are cost and availability.

A.)



B.)

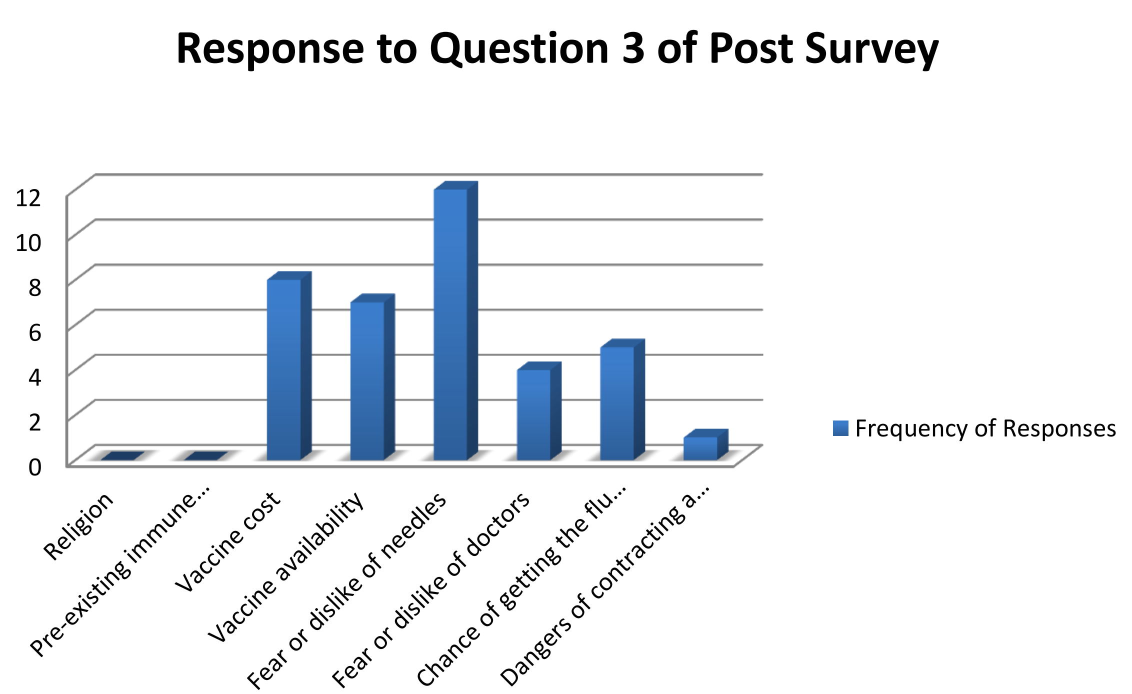
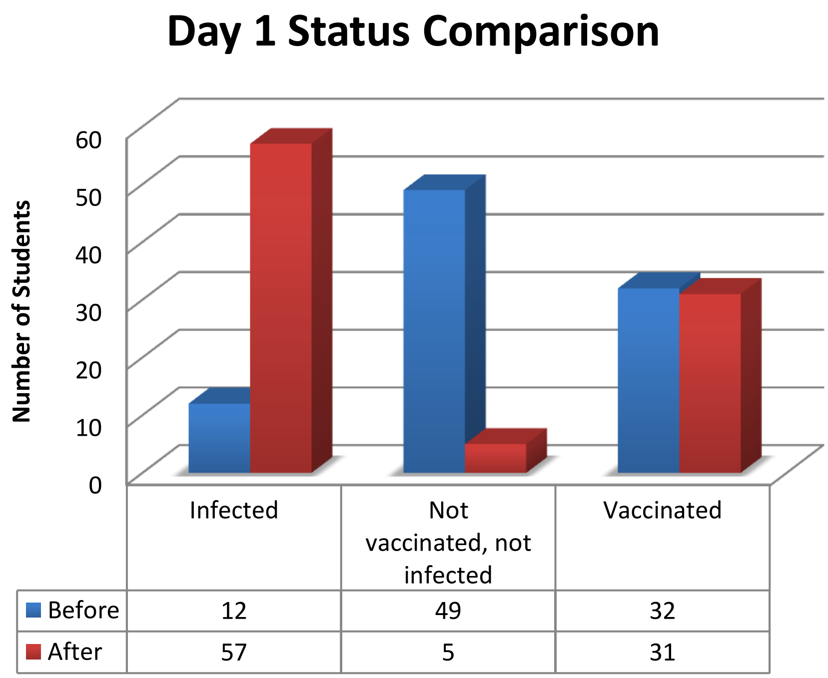


FIGURE 2: Preliminary (A) and Post-Simulation (B) Responses to: "If you generally do not get the seasonal flu vaccine or do not intend to this year, do any of the following reasons prevent you from getting the flu vaccination?"

Figure 3A represents the simulation of flu transmission within the population without effective herd immunity. On day 1, 27% of the Morgan 3 residents were assigned "vaccinated" statuses while 63% were "not vaccinated, not infected," and 10% were assigned the "infected" status. As seen in figure 3A some confusion existed among the participants regarding the simulation instructions. We only passed out 10 "infected" wristbands; however, our results show that 12 students started out their day with the "infected" status. Also, our simulation procedure had stated that "vaccinated" individuals would retain their status throughout the course of the day, meaning that "vaccinated" students would not become "infected", nor would they become "not vaccinated, not infected" (susceptible). The results showed that one individual reported a "vaccinated" status in the morning and an "infected" status in the evening. We also noticed one individual that reported being "infected" in the morning, and "not vaccinated, not infected" at the end of the day 1 simulation. We can conclude that possibly the instructions were not completely clear, or that the survey format or status descriptions were confusing to participants. Most significantly, the results of the day 1 simulation lacking herd immunity demonstrate a vast increase in the number of infected individuals in the population over the course of the day (Figure 3A).

On day 2 of the simulation herd immunity was modeled by increasing the percentage of vaccinated individuals to the threshold number of 80%. On this day 10 individuals were initially assigned the "infected" status, 76 were "vaccinated," and 10 were assigned the "not vaccinated, not infected" status. Only 5 out of the 10 susceptible participants reported a change in status to "infected" over the course of the day. Thus, the number of "infected" individuals by the end of day 1 dwarfs the number of "infected" individuals by the end of day 2. Though not all of the initially "infected" or "vaccinated" individuals responded to the survey, our results hold due to the fact that all of the susceptible individuals responded that they were either infected or still susceptible. Also, it seems as though the confusion had diminished by day 2, as all of the responses were consistent with the instructions and expected response outcome (Figure 3B).

A.)



B.)

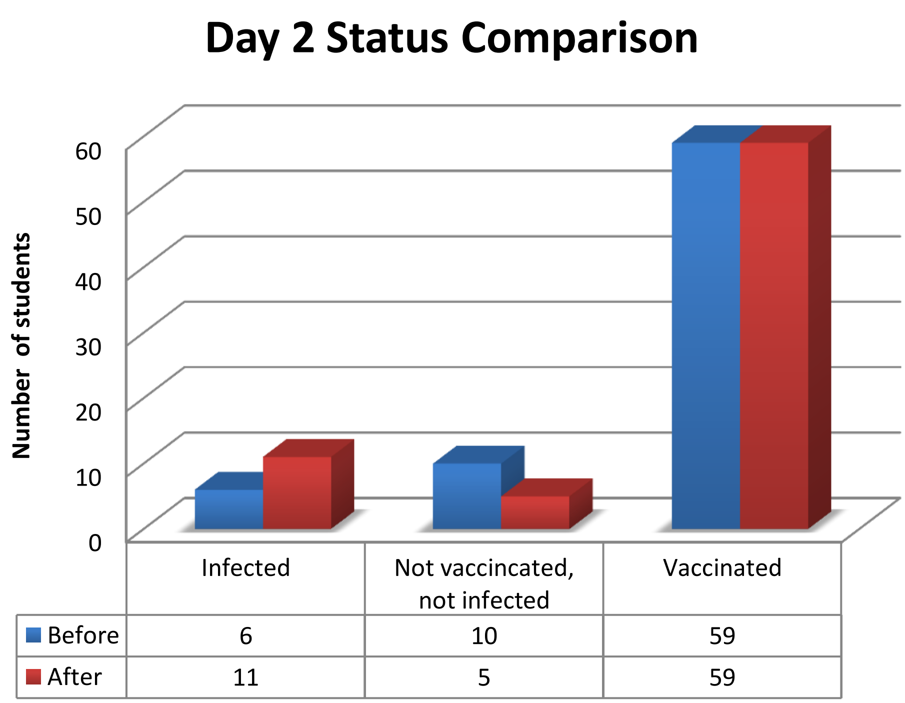


FIGURE 3: Day 1 (A) and Day 2 (B) Simulation Status Comparisons

As seen in figure 4, the simulated transmission rate of the seasonal flu on day 1 was 92%, while it was only 50% on day 2. This 42% decrease in transmission rate is attributed to the implementation of herd immunity within the population. This means that on day 1 92% of susceptible individuals became "infected," while only 50% of the susceptible individuals reported an "infected" status on day 2, as a result of the inhibition of the chain of infection.

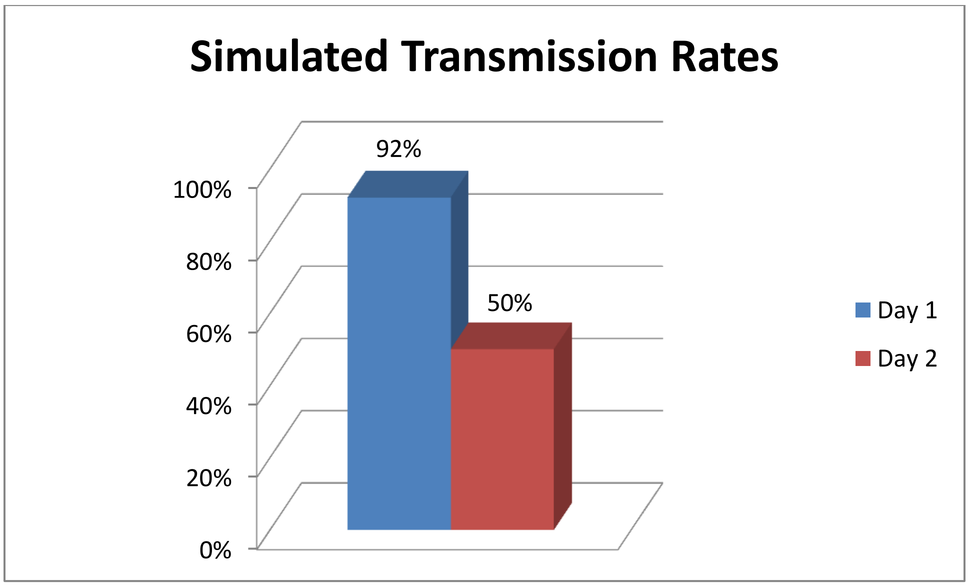


FIGURE 4: Comparison of Transmission Rates on Days 1 and 2 of Simulation

The students' attitudes towards vaccination before and after the completion of the simulation were evaluated via questions 2 and 3 of the post-survey. We asked the population if they intended to receive a seasonal flu vaccine before they participated in the simulation, and if they had reconsidered their decision upon participating in our educational program. As seen in figure 5, "yes" responses increased by 33% and "I wasn't sure/not sure" responses increased by 40% while the number of participants answering that they would not get a flu vaccine decreased by 23%. It can be postulated that the students' participation in our simulation in combination with our educational measures changed their views on vaccination.

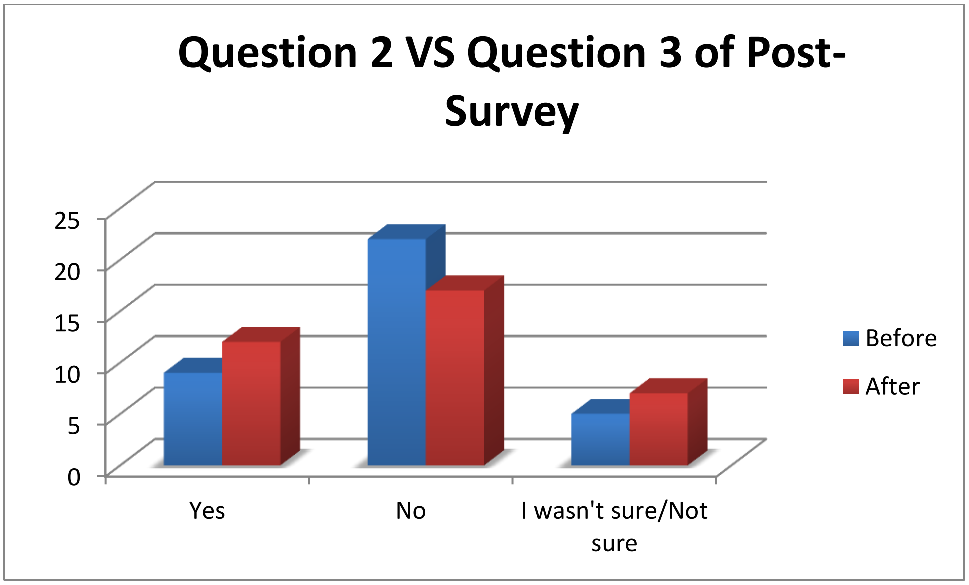


FIGURE 4: Comparison of Responses to Question 2 ("Before participating in this simulation, did you intend to get a seasonal flu vaccine this fall?") and Question 3 ("After participating in this simulation and reading the information given to you regarding the seasonal flu vaccine, do you now intend to get a seasonal flu vaccine this fall?") of the Post-Simulation Survey

In question 6, we asked students whether they would take advantage of the opportunity to receive a flu vaccine for free on campus. Figure 6 represents the percentage of our population that would make use of this service, with 64% of students showing interest.

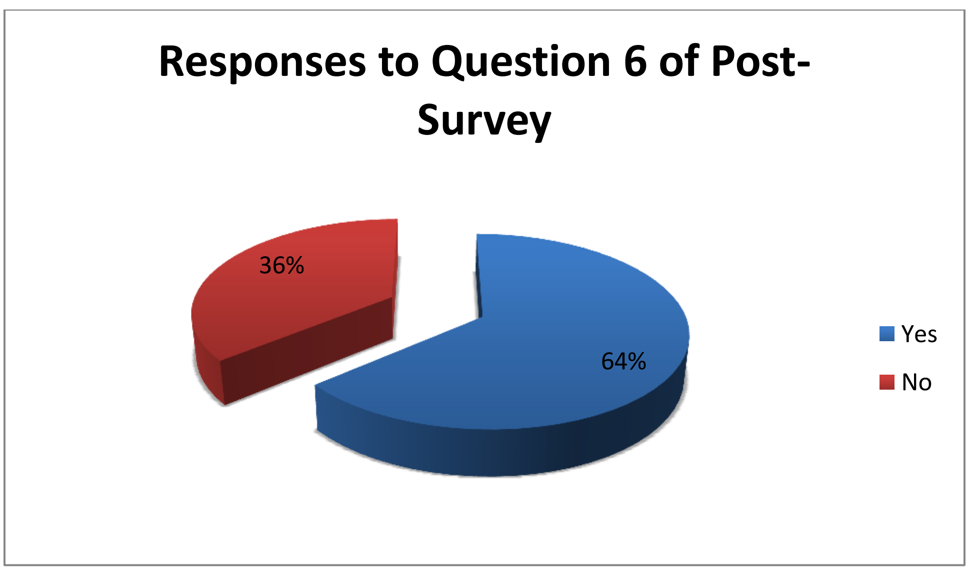


FIGURE 6: Responses to "If the seasonal flu vaccine was offered for free in an on-campus vaccine clinic, would you take advantage of this opportunity?"

Using the software package ODE45 in Matlab, our project group was able to solve the differential equations of the S-I-R model. Figure 7 are graphs generated from the plot function of Matlab. The plot used the solutions of the modeled system of differential equations. The solution contained a two column matrix representing a fraction of the population and a fraction of the overall time period. The first and second columns were used for the x and y axes of figure 7, respectively. We used the data from day one and day two of our simulation to obtain figure 7. Figure 7A mathematically predicted that the herd immunity would not occur on day one due to the drastic increase in the infected portion of the population. This was demonstrated by the positive slope of the curve that represents the infected portion of the population and the downward linear movement of the susceptible curve. Figure 7B predicted that herd immunity would occur in the population on day two due to the mathematical relationship that occurred between the infected curve and susceptible curve. Figure 7B shows a small drop in the susceptible curve and small rise in the infected curve that quickly move towards a constant.

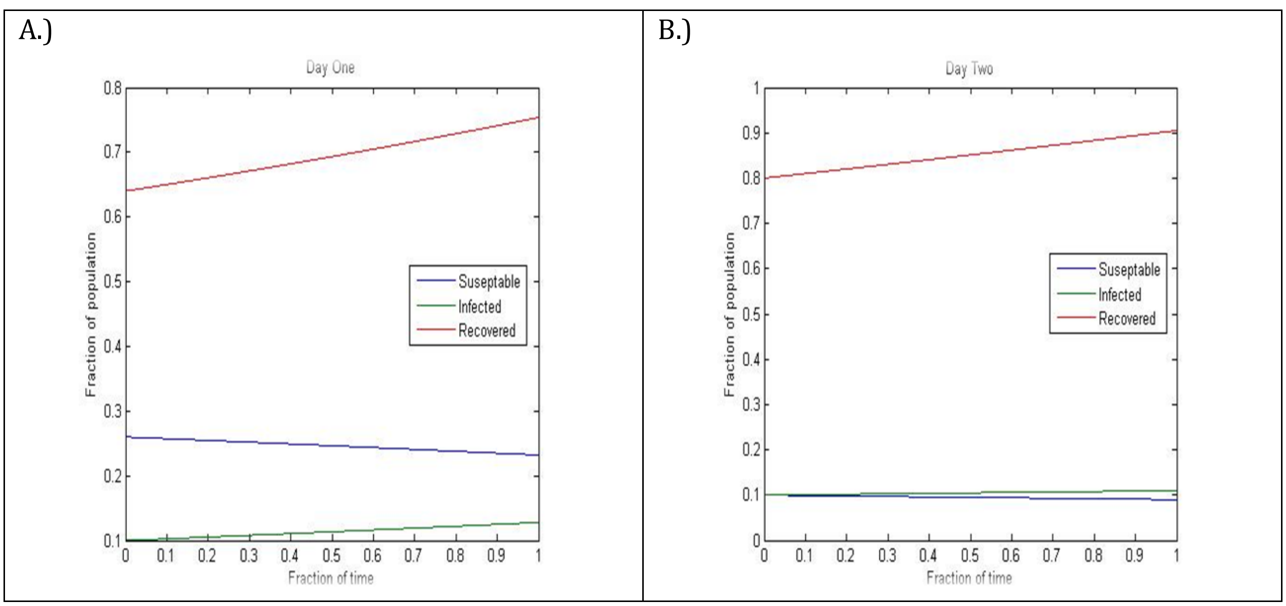


FIGURE 7: Graphical representation of the mathematical model of (A) day one of the simulation and (B) day two of the simulation.

DISCUSSION

We've stated that our project identified a need for herd immunity education on the WPI campus. This was done with the use of surveys administered to both the WPI faculty and the population used in our simulation. In our preliminary survey, the students of Morgan 3 were asked if they generally make an effort to get the seasonal flu vaccine. In figure 1, we see that close to three quarters of the students responded that they do not, which is the opposite of the 75% to 80% vaccination rate needed for herd immunity.

In an endeavor to determine why so few students get vaccinated, we asked if any of a list of possible common concerns reduced their likelihood of becoming immunized, the results of which are summarized in figure 2a. The most common reason chosen was "fear or dislike of needles" followed closely by "chance of getting the flu from the vaccine." The next most chosen responses were "vaccine availability," "vaccine cost," and "dangers of contracting a more serious illness." We deliberately included misconceptions as responses to this question to find out how many students were affected by misinformation. Because the students were not aware of the purpose of our survey, one student approached us with a concern regarding the form of the question. She expressed to us that "danger of contracting a more serious illness such as autism" on our preliminary survey was "extremely offensive" and that we should remove it as an option for the question. She also suggested that we note next to the option that "there is no valid link" between the two. It is understandable that this concerned individual did not know that the survey was designed to test the knowledge of the students, as we were looking to get a blind number of students that believe this misconception.

It is important to note that two students responded that they, in fact, have a pre-existing immune deficiency that would prevent them from getting vaccinated. This is exactly the type of person that is protected when herd immunity is achieved, thus it was extremely important that the population in our project come to understand that they would be protecting fellow members of the WPI community when vaccinating themselves. We hoped that the fact that we were able to say definitively that immunocompromised individuals exist in the population would be a driving force for the acceptance of public health education.

We intended to investigate the impact of influenza-like illnesses on student absences by surveying professors at WPI. An unexpected result of this survey was the demonstration that professors share many of the misconceptions about vaccination. One professor stated in an open response, “I do not believe in flu vaccinations in young adults. Their immune system should be able to deal with it.” This professor is neglecting to recognize the existence of immunocompromised individuals in the WPI community and the fact that vaccination rates among the rest of the population can protect such students. Fortunately, this opinion is not shared by all WPI faculty members. A professor commented, “Every year my family getst [sic] the flu vaccine. Last year was the first time I did not get it. My colleagues were sick all the time. I was not sick once!!” Though this individual makes an effort to receive the flu vaccine, they appear conscious that their peers may not be promoting herd immunity through vaccination, and consequently the flu is spread within this sub-population. The combination of the above data demonstrates quite clearly the need for education about the flu vaccine and why herd immunity is important.

As previously mentioned, the researchers developing the Geelong Hospital study found it difficult to determine the appropriate resources to invest in an educational simulation (Page 15). The flu absolutely will “occur,” thus it is reasonable to invest time, money, and energy into education. Flu season will make its presence known, and cases of the flu will be seen each year. This is especially true in academic settings such as college campuses, where individuals are constantly in close contact with one another, promoting rapid transmission of the virus. Thus, there is no question that the *Herd Immunity and You* educational simulation prepared students for an event that is most definitely going to occur. It is imperative that college students understand herd immunity and its benefits during the seasonal flu season to protect their peers from illness. This preparedness is just as important as disaster situation preparedness in a hospital setting, as the seasonal flu impacts the lives of many college students, especially those who are unable to be vaccinated. Herd immunity provides many benefits, and the simulation aimed to encourage students to establish herd immunity by increasing vaccination rates on campus.

Following the identification of this need, we implemented our designed simulation as described in the *Materials and Methods* section (Page 24). We used the "hands on" learning approach in our herd immunity simulation developed from the United Nations effort to educate individuals about disaster preparedness. This tactic helped to engage students and allow them to grasp the importance of herd immunity through their active role in the educational project.

The success of our simulation of herd immunity is demonstrated by the 42% reduction in seasonal flu transmission rates seen in figure 4. This illustrates the effectiveness of herd immunity, and our goal was to use this data in our presentation to encourage flu vaccination in order to approach the herd immunity threshold and protect the population. Furthermore, the transmission of the virus and the symptomatic status of each individual were accurately represented by the way the students used the materials given to them. Some students placed their stickers (representing the virus) on visible areas of their body including their faces and shirts. These students represented the "symptomatic carriers" of the virus within the population. Other students placed their stickers on the inside of the wristbands where they were not visible to other participants. These students represented "asymptomatic carriers" of the virus within the population. An asymptomatic carrier is someone who is infected with a pathogen and can transmit it but does not actually "get sick." *Herd Immunity and You* was designed with the Geelong Hospital study in mind, as it was found that active participation in a simulation has the highest educational value (Page 15). Our project provided participating WPI students with a learning experience in which they were actively engaged and involved in a physical manner. The success of our simulation, however, did not necessarily mean that our educational goals would be met.

We obtained extremely good data while running our simulation, but unfortunately we had trouble getting students to attend our post-simulation focus group. This was the point at which we explained the idea of our project, the facts about the flu and flu vaccines, and why herd immunity is so important. However, because we could not force students to attend out presentation, we only ended up with 7 attendants, even with the promise of free Dunkin' Donuts gift cards. Following the focus group, we also sent out the PowerPoint presentation, but we have no way to verify how many students read the included information. This was the biggest problem we ran into over the course of our project: how to get students to accept the educational material being offered.

It is our belief that the execution of this project would have been simpler and the educational value greater had we had the support of the NSO staff, as we encountered several issues with staff cooperation over the course of our project. Ideally, as part of the execution of our simulation, we would have liked to involve the participating Resident Advisors by having a training session for them. They would have learned the basics of herd immunity, as well as understood the details of our simulation. This would have allowed them to help the participating students with concepts and instructions during the course of the simulation. Unfortunately, the three members of our IQP team were unable to coordinate such support. Again, increased man-power and a large team of administrators would have greatly aided in our simulation's success, as demonstrated by prior successful simulations that were outlined in *The Educational Value of Simulations* (Page 14).

In our initial meeting, we had intended to explain the simulation procedure and answer students' questions between 7:15 and 7:30 on the evening of Sunday, August 21. This was the time allotted to us by an RA of the floor we were working with. We had asked well in advance of the meeting to ensure that we would not encroach on the time the Insight staff needed to talk to the students. We began by explaining what herd immunity was and then proceeded to outline the instructions for the students. At this time the RA began to signal to us that we needed to begin to wrap up our talk because the CAs had arrived to bring the students to their next activity. As a result, our fifteen-minute talk was abbreviated to only five minutes, which allowed time for only one question to be answered: "Where is the wedge?" Because of this we were not able to ensure to the degree that we would have liked that the students understood the instructions given them. This was also the only time that we were able to communicate with the students directly prior to the start of the simulation. Additionally, the meeting was located on the Morgan 3 floor, which was not ideal, and due to the lack of cooperation we were unable to book a room that would have been better suited to our purposes. The 96 students were seated on the floor of the hallway, and thus most of the students could not hear as we were forced to stand at the end of the hallway and try to shout our information at them. We could not really see the students at the end of the hallway, nor could we determine if they were actually paying attention. If we had had more cooperation and sheer man-power our simulation could have been successfully scaled up to the entire freshman class, allowing for more widespread education and herd immunity awareness.

Though we faced limitations in educational portion of our project, the results of our post-survey reflect a change in attitude among the participants. As demonstrated by figure 5, following the completion of our program, the number of people intending to get a flu vaccine this fall increased. This is correlated with the data seen in figure 2B regarding common concerns associated with the vaccine. We can surmise that the frequency of respondents who chose "fear or dislike of needles" decreased as students realized that vaccinating themselves would protect others. Presumably, preserving the health of their peers could serve as an impetus for overcoming their fears. Following our program, fewer students responded that they were concerned about acquiring the flu from the vaccine, with the response rate dropping from 19 to 5. Also, the responses to "dangers of contracting a more serious illness" plummeted by 80%. It is probable that this is due to the educational materials provided, and we hope that this will result in an increased vaccination rate with the possible achievement of herd immunity.

As seen in figure 6, 64% of students surveyed would take advantage of a free on-campus flu vaccine if it were offered at WPI. There is a correlation between this result and the concerns expressed in figure 2B. Vaccine cost and availability remained two of the most common impediments to students getting the seasonal flu vaccine. This demonstrates that developing a free on-campus flu vaccine clinic would be beneficial to student health as more individuals would be vaccinated and thus protected against the flu.

It is clear that a simulation of herd immunity accompanied by educational materials was an effective form of public health education. It altered the views of students on campus and subsequently promoted the intent to get vaccinated. If herd immunity were achieved on the WPI campus all students, including those who cannot be vaccinated, would benefit. It is important for students at WPI to be aware of public health issues in our community. Helping to prevent the spread of the seasonal flu is a simple measure that students can take to make a significant impact on the health of their peers.

Recommendations

Given that our simulation of herd immunity showed a 42% decrease in seasonal flu transmission rate, we recommend that our successful program be adapted to run every year at New Student Orientation (Figure 4). If this public health initiative were expanded to include the entirety of the freshman class, a greater percentage of the WPI community would be educated about the benefits of herd immunity against the seasonal flu, specifically on a college campus. Consequently, the knowledge these students gain could influence their decision to become vaccinated, and ultimately increase the percentage of vaccinated individuals on campus until this number reaches the threshold needed for herd immunity. This endeavor would require a large staff to manage the logistics of the program as well as the distribution of materials and instructions; however, the educational and subsequent health benefits are worth the resources it would take to run this program effectively.

Furthermore, we had initially intended to propose that Health Services provide students with flu vaccinations free of charge. Following our program, when the students were asked if they would take advantage of a free on-campus vaccine clinic, 64% of students responded with "yes" (Figure 6). It therefore appears that such an initiative would be a worthwhile endeavor. Not only does our data suggest that students are interested in free on-campus vaccines, but it also demonstrates that post-simulation, the students were still not planning on getting immunized due to cost and availability of the vaccine (Figure 2). It is evident that interest in receiving the vaccine does indeed exist in the population, and that a free on-campus clinic would certainly solve the problem of cost and availability for students. Running the *Herd Immunity and You* program annually would increase interest and subsequently benefit the health of the WPI community if executed in combination with a free seasonal flu vaccine clinic on our campus.

It is clear that a simulation of herd immunity accompanied by educational materials was an effective form of public health education, and could be applied in the future to further the knowledge of WPI students. It altered the views of students on campus and subsequently promoted flu vaccination. If herd immunity were achieved on the WPI campus all students, including those who cannot be vaccinated, would benefit. It is important for students at WPI to be aware of public health issues in our community. Helping to prevent the spread of the seasonal flu is a simple measure that students can take to make a significant impact on the health of their peers.

APPENDICES

Appendix 1: IRB Exemption

100 Institute Road
Worcester, MA 01609-2280, USA
508-831-5000, Fax 508-831-6090
www.wpi.edu

Worcester Polytechnic Institute IRB #1
IRB 00007374

1 June 2011
File:11-091

Worcester Polytechnic Institute
100 Institute Road
Worcester, MA 01609

Re: IRB Application for Exemption 11-091 "Herd Immunity and You"

Dear Prof. Rulfs,

The WPI Institutional Review Committee (IRB) has reviewed the materials submitted in regards to the above mentioned study and has determined that this research is exempt from further IRB review and supervision under 45 CFR 46.101(b)(1): "**Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.**"

This exemption covers any research and data collected under your protocol from 1 June 2011 to 31 May 2012, unless terminated sooner (in writing) by yourself or the WPI IRB. Amendments or changes to the research that might alter this specific exemption must be submitted to the WPI IRB for review and may require a full IRB application in order for the research to continue.

Please contact the undersigned if you have any questions about the terms of this exemption.

Thank you for your cooperation with the WPI IRB.

Sincerely,

Kent Rissmiller

Kent Rissmiller
WPI IRB Chair

APPENDIX 2: PRELIMINARY SURVEY AND EMAIL

The text of the first email, sent on 8/18/11 to the population used in our project, is below:

> Hello Residents of Morgan 3,
>
> Welcome to WPI! As part of my group's Interactive Qualifying Project (IQP) we are running a simulation with the members of your residence hall floor. We will reveal the details of our project when you arrive on campus, but for now your participation in an online survey is required. Please click the following link and answer the provided questions.
>
> Get excited! Supporting other students in each other's academic endeavors will be an integral part of your WPI experience.
>
> https://spreadsheets.google.com/spreadsheet/viewform?formkey=dGhGbzA3WDdHM01lRlpuYXRfX0ZmeHc6MQ
>
> Thank you and enjoy the rest of your summer!

The hyperlink in this email brought students to our preliminary survey, which read as follows:

1. Has a doctor or other healthcare professional ever diagnosed you with the seasonal flu?
2. Do you make an effort to get the seasonal flu vaccine each year?
3. Do you intend to get the seasonal flu vaccine this fall?
4. If you generally do not get the flu vaccine or do not intend to this year, do any of the following reasons prevent you from getting the flu vaccination? (Multiple answers accepted)
    - Religion
    - Pre-existing immune deficiency
    - Vaccine cost
    - Vaccine availability
    - Fear or dislike of needles
    - Fear or dislike of doctors
    - Chance of getting the flu from the vaccine
    - Danger of contracting a more serious illness (Autism, Guillain-Barré syndrome, etc.)
    - Other (please specify)
5. Would you consider participating in an on-campus student simulation of herd immunity to a communicable disease such as the flu?
6. If the seasonal flu vaccine was offered for free in an on-campus vaccine clinic, would you take advantage of this opportunity?

Appendix 3: Day 1 Status Survey and Email

The text of the second email, sent on 8/22/11 to the population used in our project, is below:

> Hello Residents,
>
> Below you will find the link for the day one survey. This survey is two questions long. This is how we are gathering the data on what you did today, so it is incredibly important that each of you fill this out. Please do not complete the status survey until you are in your rooms for the night, as this will maximize contact time with other individuals.
>
> https://spreadsheets.google.com/spreadsheet/viewform?formkey=dFZvel9DN0N4Qm50MS1NcWhEMDhOb Wc6MQ

The hyperlink in this email brought students to our day 1 status survey, which read as follows:

1. What was your infection status at the start of the day today (please select one)?
    - Infected
    - Vaccinated
    - Not vaccinated, not infected
2. What was your infection status at the end of the day today (please select one)?
    - Infected
    - Vaccinated
    - Not vaccinated, not infected

Appendix 4: Day 2 Status Survey and Email

The text of the third email, sent on 8/23/11 to the population used in our project, is below:

> Hello,
>
> Below is the survey for the second (and final) day of the simulation. Again, please don't fill out this survey until you are in your rooms for the night. Also, the day one survey from yesterday is still open. If you have not yet done so, please complete this as well. It is very important that we are able to collect the data from both days and from all individuals. We are holding a short presentation and question and answer session tomorrow from 4:30-5:00 in Salisbury Labs room 105. We will be revealing the details of our project as well as your role in it. We would love to see all of you there!
>
> https://spreadsheets.google.com/spreadsheet/viewform?formkey=dDdsaEw3bWFDX2J5QjFfaUtKUm1WSmc6MQ

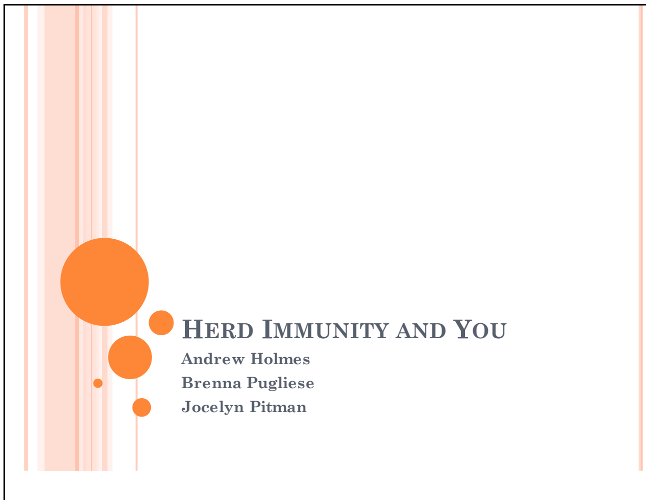
The hyperlink in this email brought students to our day 2 status survey, which read as follows (it was the same as the day 1 status survey):

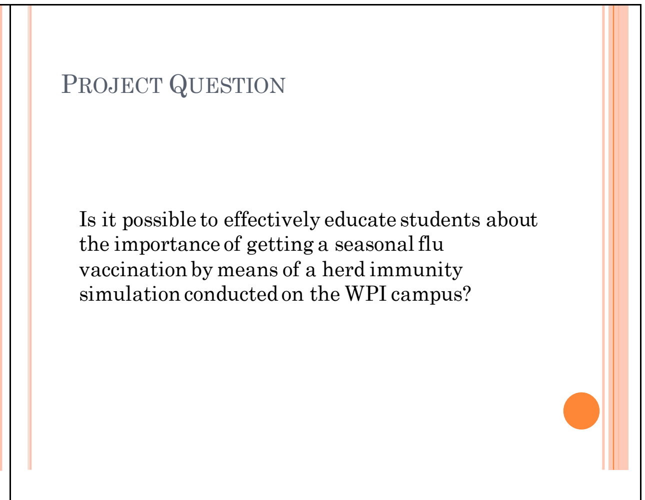
3. What was your infection status at the start of the day today (please select one)?
    - Infected
    - Vaccinated
    - Not vaccinated, not infected

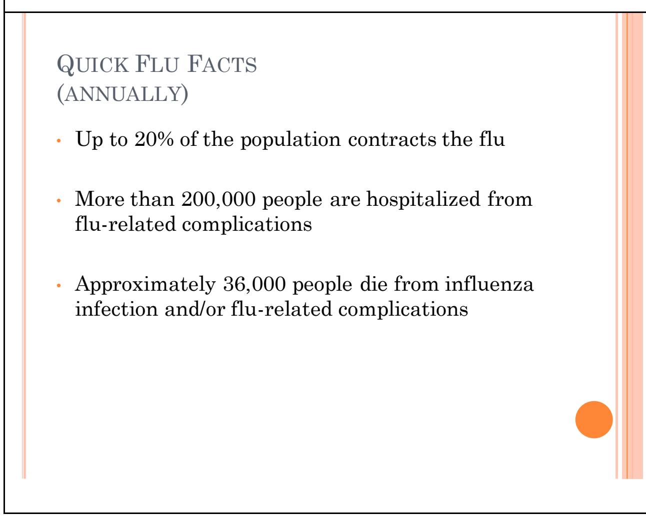
4. What was your infection status at the end of the day today (please select one)?
    - Infected
    - Vaccinated
    - Not vaccinated, not infected

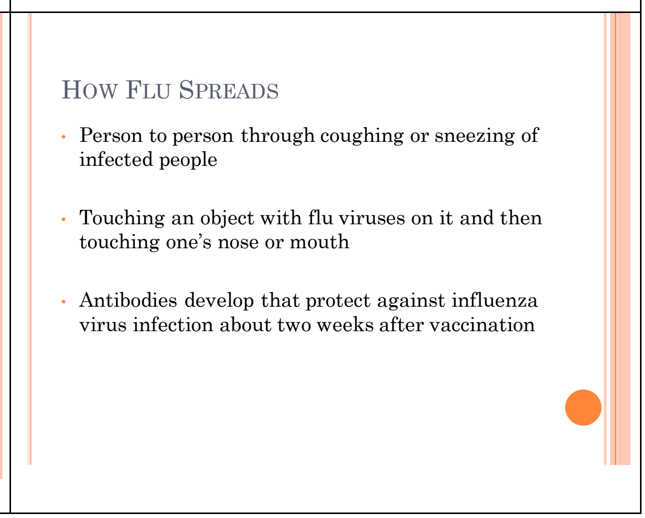
APPENDIX 5: POST-SIMULATION PRESENTATION

Below is the presentation shown in our focus group on 9/28/11. It explained our project and the outcome of our simulation to the students.









What do Immunizations do?

- Prepare a person's body to fight sickness
- Contain either a dead or attenuated pathogen that causes a particular disease
- The body practices fighting the disease by making antibodies that recognize the pathogen
- The antibodies allow the body to quickly combat the virus
- If exposed to the infectious agent, the person will not become sick

Common Vaccination Misconceptions

- Flu immunizations can give you the very disease you are trying to prevent.
- The vaccine can cause Autism.
- It is likely that you will get Guillain-Barre Syndrome from the flu vaccine.
- I'm the only person I protect when I get a flu vaccination.

What is Herd Immunity?

- Vaccinating a portion of a population to provide protection to the unvaccinated
  - 75%-80% must be vaccinated for success
- Only a small percentage of the population can be left unvaccinated
  - Those who cannot safely receive vaccines due to medical conditions
  - Can help reduce the spread of disease to the unimmunized

How Does it Work?

- Difficult for a contagious disease to maintain a chain of infection if a large percentage of a population has been immunized
- The higher the percentage of immunized people, the lower the likelihood that a susceptible person will come into contact with an infected individual

In Our Simulation…

- Day One: Without Herd Immunity
  - 10% of students were "infected"
  - 26% of students were "vaccinated"
  - 64% of students were "not vaccinated"
- Transmission Rates
  - Started out with 48 people "not vaccinated"
  - 44 people were "infected" by the end of the day
  - Seasonal flu transmission rate of 92%

- Day Two: With Herd Immunity
  - 10% of students were "infected"
  - 80% of students were "vaccinated"
  - 10% of students were "not vaccinated"
- Transmission Rates
  - Started out with 10 people "not vaccinated"
  - 5 people ended the day as "infected"
  - Seasonal flu transmission rate of 50%
- Overall, this is a 42% reduction in the transmission of the seasonal flu

Appendix 6: Post-Simulation Survey and Email

The text of the final email, sent on 9/28/11 to the population used in our project, is below:

> Hey again,
>
> Tonight we held our post-simulation focus group. We would like to get your opinions on the simulation and anything you may have learned about the seasonal flu and the seasonal flu vaccine as a result of this activity. Even if you did not attend the focus group, we would greatly appreciate your taking the time to reply to this short survey. This is the final part of our project, so it would be fantastic if you could help us gather as much data as possible. The survey can be found at:
>
> https://docs.google.com/spreadsheet/viewform?formkey=dG9zRmdCN3hUTWQ4YnF1dXIwTDRLLVE6MQ
>
> Thanks again for all your help Morgan 3!

The hyperlink in this email brought students to our post-simulation survey, which read as follows:

1. Did you attend the post-simulation focus group?
2. Before participating in this simulation, did you intend to get a seasonal flu vaccine this fall?
3. After participating in this simulation and reading the information given to you regarding the seasonal flu vaccine, do you now intend to get a seasonal flu vaccine this fall?
4. If you do not intend to get a flu vaccine, do any of the following reasons prevent you from getting the flu vaccination? (Multiple answers accepted)
    - Religion
    - Pre-existing Immune Deficiency
    - Vaccine cost
    - Vaccine availability
    - Fear or dislike of needles
    - Fear or dislike of doctors
    - Chance of getting the flu from the vaccine
    - Danger of contracting a more serious illness (Autism, Guillain-Barré Syndrome, etc.)
    - Other (please specify)
5. If you now intend to get a flu vaccine and did not intend to get one before the simulation, is there one piece of information you learned that changed your mind? (open response)
6. If the seasonal flu vaccine was offered for free in an on-campus vaccine clinic, would you take advantage of this opportunity?

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