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Using information technology to model hand-washing behavior and to improve policies impacting elementary school absenteeism due to influenza

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USING INFORMATION TECHNOLOGY TO MODEL HAND-WASHING BEHAVIOR AND TO IMPROVE POLICIES IMPACTING ELEMENTARY SCHOOL ABSENTEEISM DUE TO INFLUENZA

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USING INFORMATION TECHNOLOGY

TO MODEL HAND-WASHING BEHAVIOR AND TO IMPROVE POLICIES

IMPACTING ELEMENTARY SCHOOL ABSENTEEISM DUE TO INFLUENZA

A Dissertation

Submitted to the Faculty

of

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Galina V. Miller

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of

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To my son, Benjamin for his inspiration and empowerment.

To my parents, Nina and Veniamin for their love, support, and encouragement.

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ABBREVIATIONS

ABM	Agent-Based Modeling
ANN	Artificial Neutral Networks
CDC	Centers for Disease Control and Prevention
CPU	Central Processing Unit Power
DES	Discrete Event Simulation
HIV	Human Immunodeficiency Virus
MI	Minimal Intervention
SARS	Severe Acute Respiratory Syndrome
SD	System Dynamics
SEIR	Susceptible-Exposed-Infected-Recovered
SIR	Susceptible-Infected-Recovered
UML	Unified Modeling Language
WHO	World Health Organization
YLL	Years of Life Lost

ABSTRACT

Miller, Galina V. Ph.D., Purdue University, May 2016. Using Information Technology to Model Hand-Washing Behavior and to Improve Policies Impacting Elementary School Absenteeism Due to Influenza. Major Professor: James E. Dietz.

This dissertation presented several problems on the analyses of influenza propagation by indicating how agent-based modeling can be employed to measure the effectiveness of control measures and assist in improving health policy to decrease absenteeism among elementary students. The primary question posed was as following: "What is the effect of hand hygiene on the possible influenza incidence rates among school children?" After creating an agent-based model representing the influenza transmission dynamic, the incidence rates were calculated based on the hand-washing success rates. The statistical results from the simulation model were displayed in graphical format.

Finally, the author addressed the issue of measuring validity of the model. The statistical analysis on absenteeism from flu was performed using data on missed school days in classrooms in one of the local schools in Tippecanoe County, where students exercised hand washing with soap on a regular basis. The analyses also considered data on absenteeism among children who were not required to perform hand washing routinely. This agent-based simulation method is an innocuous and economical approach to model the propagation of respiratory diseases such as influenza. It enables the researcher to model individual behaviors and interaction among individuals and their environment. This feature enables the researcher to represent influenza transmission dynamic more realistically and to provide in-depth analyses to inquiries for epidemiologist and public health professionals.

CHAPTER 1. INTRODUCTION

Analysis of the recent data (CDC, 2014) on morbidity and mortality rates indicated that influenza represents a serious health risk and economic burden to the U.S. and worldwide populations (CDC, 2014). Research suggested that it remains one of the major causes for morbidity, mortality, disability, absenteeism, and lost productivity in the U.S. population and abroad (Anderson, 2008; Bright et al., 2010; CDC, 2014; Dietz & Black, 2012; Greenhouse, 2009; Guinan et al., 2002; Hammond et al., 2000). Seasonal influenza increased monetary expenses in families with school children and resulted in more school and work days lost (Hammond et al., 2000; Neuzi et al.,2002; Sandora et al., 2008). Moreover, the absence of paid sick leave polices increaseed the risk of rapid circulation of the virus during the flu season in workplaces and educational institutions (Greenhouse, 2009).

Evidence suggested that routine hand hygiene is an effective, easy, and low-cost intervention to reduce incidence rates and absenteeism due to respiratory and gastrointestinal diseases among school children (CDC, 2014; Ingelsby, 2006; Jumma, 2005; Pittet & Boyce, 2001; Stebbins et al., 2011; WHO, 2009). Evidence from previous research indicated that hand washing with soap is rarely practiced in society at large and represents a real challenge to make hand washing with soap a routine habit performed by all students throughout the country anywhere (Borchgrevink et al., 2013; CDC, 2014; Guinan et al., 2002). Furthermore, even though the positive impact of hand hygiene is biologically evident, policies on mandatory hand hygiene practices, cleaning, and disinfection of the classroom during the flu season in elementary schools do not exist (Bright, 2010; Guinan et al., 2000).

Simulation modeling tools are shown to be effective tool for analyzing the influenza dynamic and quantifying the effectiveness of the control measures on flu spread in an educational setting (vaccination, use of antiviral drugs, enhanced ventilation, use of masks) (Chao et al., 2010; Dietz et al., 2012; Emrich et al., 2007; Epstein, 2009; Halder et al., 2010; Skvortsov et al., 2007). However, there are no computer epidemiological models assessing the efficacy of non-pharmaceutical control and preventative measures such as hand hygiene, on the influenza course. Developing a simulation model of influenza propagation in an educational environment will facilitate in-depth understanding of the flu course among school children and measure the efficacy of hand hygiene on the incidence rate. The outcomes of this project will enable scientists and key stakeholders to determine and measure the effectiveness of certain mitigation strategies that might improve policies impacting absenteeism among school children.

1.1 Scope

Decreasing morbidity, mortality, and disability is an integral part of improving the quality of life in our society. To achieve this objective, it is critical to examine and assess what interventions reduce these problems innocuously, effectively, and economically. Additionally, a valid evaluation of the effect of non-pharmaceutical control measures is essential to determine efficient planning and mitigation strategies to reduce health risk, ease the economic burden of the seasonal flu, and limit the threat of future flu pandemics. This dissertation analyzes influenza propagation by indicating how an agent-based simulation modeling approach can be employed to measure the effectiveness of control measures and to assist in improving health policy to decrease absenteeism among elementary students. The primary objectives of this project are to examine and measure:

- how the physical environment, behaviors, and policies related to hand hygiene impact influenza propagation in an educational setting.
- the effect of a control measure (hand washing with soap) on the influenza dynamic in a school environment.

An agent-based model representing the influenza propagation dynamic in a school setting was created and the incidence rates were calculated based on the hand-washing rates. The statistical results from the model were displayed in a graphical format. The researcher employed incidence rates of elementary school children contracting influenza as an indicator of how disease spreads in the educational setting. The author also addressed the issues related to measuring the validity of the model. The statistical analyses on absenteeism because of flu was performed using data on missed school days in food-allergy classrooms in one of the local schools where students exercise hand washing with soap on a regular basis. The data were compared with data on absenteeism among children in the classrooms where hand-washing (intervention)was not implemented.

1.2 Significance

This dissertation is designed to examine the impact of the physical environment on the influenza disease course and to study incidence rates among elementary school children employing a simulation modeling approach. After the influenza course was properly characterized, the author measured the efficacy of control measures such as hand washing with soap on the influenza course. Hand washing is one of the most cost-effective and innocuous methods to control and prevent the risk of communicable diseases in society, to decrease absenteeism in schools, and to increase overall productivity (CDC, 2014; Ingelsby, 2006; Jumma, 2005; Pittet & Boyce, 2001; Stebbins et al., 2011; WHO, 2009). Inadequate hand-washing compliance and inappropriate hand-washing practices among school children result in greater health risks in society and they constitute a substantial economic burden (e.g., CDC, 2014; Dietz et al., 2012; Guinan et al., 2002; Stebbins et al., 2011).

The other issue that illustrates the importance of this research comes from the field of epidemiology. The hand-washing technique could be classified under the epidemiological concept of Occam's razor, or minimum intervention (Black, 2014). According to this concept, a minimal intervention is the simplest and least expensive intervention that works. It is an ideal population-based approach because compliance is positively influenced and results in that likelihood that simple versus complex behaviors will be performed (Black, 2014). If only 5% of the population uses the intervention, the result would be millions of people using the intervention and there would be a substantial reduction in morbidity, mortality, and disability (Dietz & Black, 2012).

Additionally, novel information technology tools such as agent-based simulation offer innocuous and economical approaches to modeling the propagation of respiratory diseases such as influenza. Agent-based simulation enables the researcher to model complex individual behaviors and interactions among individuals and their environment. This feature enables the researcher to represent the influenza transmission dynamic more realistically, providing in-depth analyses to epidemiological inquiries. By ascertaining and assessing the effect of hand hygiene on incidence rates among school children, this research will provide epidemiologists and key stakeholders with results on the efficacy of non-pharmaceutical intervention strategies. This in turn, might improve policies impacting absenteeism among school children and increase overall productivity during the flu season.

1.3 Research Questions

1. What is the effect of hand washing on incidence rates and absenteeism due to influenza in educational environments?

2. Is there a relationship between hand washing and incidence rates among elementary students?

1.4 Assumptions

The assumptions of this study were:

- There was a need to examine the effect of non-pharmaceutical intervention (hand washing with soap) on the influenza incidence rates among elementary school children to gain insights into the cause of influenza transmission in physical environments.
- There was a need to examine how agent-based modeling approach can be employed to quantify the effectiveness of control measures and improve policies impacting absenteeism among elementary school children.
- This study assumes hand washing with soap is an effective measure to decrease influenza related absenteeism and incidence rates among elementary school children in physical environment.
- The agents in the created model represented elementary school children familiar with the technique of proper hand washing with soap.
- The agents used in the model could appropriately represent each individual with adequate specificity for the model to be accurate.
- The data acquisition software was valid and reliable and it worked properly.
- The research approach selected for this project was appropriate for elucidating the research questions.

1.5 Limitations

The limitations of this study were:

- This study was limited to the natural history or observational study design of the influenza infection course.

- The theoretical framework used for the simulation experiment was based on the existing susceptible-exposed-infected-recovered (SEIR) framework for the influenza virus circulation.
- This study was limited to the incorporation of hand washing with soap intervention among elementary school children.
- This study was limited to hand washing performance practices exercised by agents four times per day based on the seven-hour school day period.
- The output results of this study were limited to the time the agents were susceptible to the influenza virus until the time they became immune to it.

1.6 Delimitations

The delimitations of this study were:

- No specific cases were incorporated into the model.
- Agents in the simulation experiment represented elementary school children in K-6 grades in one of the elementary schools in West Lafayette, Indiana.
- This study did not categorize agents as per gender.
- The data from the simulation experiment was used to calculate influenza incidence rates.
- There were no other non-pharmaceutical interventions incorporated into the model.
- The period from October 2014 through May 2015 was allotted to collect the data on the influenza-related illnesses in the simulation experiment.
- The data on the absenteeism in food allergy and allergy free rooms were collected in the period from October 2014 through May 2015 in one of the local elementary school in West Lafayette, Indiana.

1.7 Definitions

In the broader context of thesis writing, the researcher defines the following terms:

absenteeism: "an excusable or inexcusable absences from elementary or secondary school" (Kearney, 2008, p.452).

agent: "a modular, self-contained, and uniquely identifiable individual" (Heath, 2011, p. 2791).

agent-based models: software demonstration arrangements comprising discrete small units (agents); collection interrelating and modifying through discrete time intervals, which grow into macrosystem (Barbati et al., 2012).

attack rate: "cumulative incidence of infection or disease in a group of people observed over time during an outbreak or epidemic" (Glatman-Freedman et al., 2012).

carrier: an individual who sheds an infectious agent, but does not have any clinical symptoms (Vynnycky & Wight, 2010).

category C threat diseases: third high-priority agents (organisms) which represent a risk to national security and have major negative health impact due to the ease of their production, accessibility, and potential for high morbidity and mortality rates (CDC, 2014).

direct contact: a contact between infected and susceptible individuals (Black et al., 2013).

disease: an outcome of an interaction of the host (e.g., an individual), the agent (e.g., virus), and the environment (e.g., fomites; Gordis, 2009).

disease distribution: the investigation of the patterns of a disease in regards to attributes such as person, place, and time (Aschengrau & Seage III, 2008).

epidemiology: "the study of the distribution, determinants of the disease frequency, injury and disability in human populations" (Black et al., 2013, p. 44)

fomites: articles that convey infection to others because they have been contaminated by pathogenic organisms (Black et al., 2013).

hand hygiene: a method of removing microorganisms from the hands (CDC, 2014).

hand washing: "defined as the vigorous, brief rubbing together of all surfaces of lathered hands, followed by rinsing under a stream of water" (CDC, 2014, para.3).

herd immunity: "the resistance of a group of people to an attack by a disease to which the large proportion of the members of the group are immune" (Gordis, 2009, p. 24).

immune: refers to an individual "who has complete protection to an infection, which results either from vaccination or previous infection" (Vynnycky & White, 2010, p. xxiii).

incidence rate: "the number of new cases of a disease that occur during specific period of time in a population at risk for developing the disease" (Gordis, 2009, p. 38.)

indirect contact: pathogens are transmitted via an intermediate source, such as contaminated surfaces (fomites Black et al., 2013).

infection: "the invasion of one organism by a smaller (infecting) organism" (Vynnycky & White, 2010, p.1).

influenza: a respiratory illness with a short incubation period, usually from 2 – 4 days, and propagates via large aerosol droplets (> 5mm), expelled by coughing and sneezing, that are inhaled (Heymann, 2008).

life expectancy: "the average number of years a person is expected to live" (Black et al., 2013, p. 275).

modeling: a methodology of elucidating real-life dilemmas, where the investigated arrangement is substituted by a simplified structure that depicts the real system or events (www.AnyLogic.com, 2013).

natural history of the disease: "the course of the disease from its inception to its resolution" (Aschengrau & Seage, 2008, p. 412).

pandemic: "the distribution of the number of observed cases is greater than expected, and a large geographic area is affected (e.g., country, continent, or world;" Dietz & Black, 2012, p. xxviii).

presenteeism: "the practice of coming to work despite illness, injury, anxiety, etc., often resulting in reduced productivity" (www. Dictionary.com)

primary prevention: "the prevention of the development of the disease by reducing exposure to disease causing agents or by immunization, denotes intervention before the disease has developed" (Gordis, 2009, p. 313).

resident flora: is located on the deeper skin layers (the sebaceous glands), and microorganisms on these layers are unassociated with hand hygiene practices (Jamaa, 2005).

simulations: "a special class of computer-based mathematical models whose behavior is dictated equations and algorithms, typically based on data, and represented by some type of computer user interface" (www.AnyLogic, 2013).

transient flora: is located on superficial skin layers and consists of infectious agents associated with nosocomial infections (Escherichia coli and Pseudomonas aeruginosa) and viruses. The transient flora has a short survival rate and high pathogenic ability (Jumma, 2005).

zoonoses: the diseases that transmit from wild or domesticated animals to humans (Quammen, 2012).

1.8 Summary

In this chapter the author provided the scope, significance, research questions, assumptions, limitations, delimitations, definitions, and other background information for the research study.

CHAPTER 2. REVIEW OF RELEVANT LITERATURE

The following literature review comprises ten sections. The first section of this chapter presents an overview of the historical perspective on the threat of pandemic influenza. The second section discusses the detrimental consequences from seasonal influenza, such as health risk and economic burden. The third section of this chapter is devoted to the problem of absenteeism. The forth section provides a description of epidemiological modeling approach as a method to forecast and measure the risk of infectious diseases transmission and assess the efficacy of preventative measures on the disease spread in populations. This section also provides an overview of the historical perspective of epidemiological modeling and types of epidemiological models. The fifth section describes types of epidemiological models. This section also gives an overview of modeling and simulation modeling and its role in solving epidemiological problems. The sixth section is devoted to the steps that are essential in creating an epidemiological model. The seventh section includes the description of agent-based simulation modeling method and the structure of an agent-based model. The eighth part of this chapter covers the epidemiology of influenza, its clinical features, its mode of its transmission, and methods to control and prevent the disease. Then it provides an overview of why school children are the disseminators of influenza. The ninth section is devoted to the hand-hygiene method as an easy, effective, and the most economical intervention to control and prevent pathogens from propagating in society. The last section is a summary of the literature review chapter. The objective of this chapter is to demonstrate how intervention measures, such as hand washing, could be an effective measure to lessen the negative impact of seasonal flu and to explicate why agent-based modeling is an accurate approach to employ to measure the efficacy of hand hygiene intervention on incidence rates among school children.

The propagation of infectious diseases is an ongoing problem in human society. One of the worrisome challenges is the prevention and control of diseases such as influenza. Influenza (generally identified as flu) represents a potential threat to the security and stability of the U.S., as it is an infectious disease with pandemic potential. Diseases are pandemic when "the distribution of the number of observed cases is greater than expected, and a large geographic area is affected (e.g., country, continent, or world" Dietz & Black, 2012, p. xxviii). Diseases with pandemic distribution are cyclical by nature, which makes them hard to predict due to the constant virus mutations (Germann et al., 2006; Larson, 2007).

2.1 Historical Perspective and Threat of Pandemic Influenza

The US suffered from three devastating lethal influenza pandemics just in the last century. For instance, the 1918-1919 (Spanish flu) pandemic resulted in 675,000 deaths in America and 50 million worldwide (Taubenberger & Morens, 2006). The Asian flu (H2N2) pandemic occurred in 1956-1958, causing 70,000 mortalities in the US and up to two million internationally (U.S. Department of Health and Human Services, 2009). The influenza pandemic of 1968-1969 (Hong Kong flu, H3N2) killed 34,000 Americans and 700,000 internationally (Dietz et al., 2012).

According to Flu.gov (2014), such pandemics occurred as a result of influenza virus mutations and can occur abruptly, gradually over time, or frequently enough that the human immune system is confused and cannot distinguish the influenza virus. Such mutations create a novel, highly contagious, and highly fatal influenza subtype that arises via infection of the same cell by two distinct influenza stains that merge. As a result, people lack immunity to the novel subtype virus that causes austere epidemics or even pandemics. The vivid example of such a genetic phenomenon is the pandemic of 2009, which was caused by a rare strain of the influenza H1N1 influenza A virus, that occurred as result of the amalgamation of the influenza viruses that reside in humans, birds, and pigs (McNeil, 2009).

Taubenberger and Morens (2006) postulated that H1N1 virus was linked to the virus that was responsible for the Spanish flu pandemic influenza. Factors contributing to the influenza pandemic proliferation in the 21st century are linked to world population growth, global mobility, high rates of an aging population, and people with chronic diseases (Quammen, 2012).

Furthermore, influenza is classified as an emergent infectious disease category C threat as a potential bioterrorist weapon (CDC, 2014). The CDC further noted that category C threat diseases refer to third high-priority agents (organisms), that represent a risk to national security and have major negative health impacts due to the ease of their production, accessibility, and potential for high morbidity and mortality rates. The next flu pandemic is unavoidable, and it is just a matter of time until the next one will strike. Data on annual epidemics of influenza demonstrate how vulnerable our interconnected world is to this infection. The primary objective of public health is to prevent diseases, injury, disability, premature death, and to protect and promote health (Aschengrau & Seage III, 2008).

Furthermore, influenza raised major public health concerns and required substantial investments for detection, prevention, and mitigation from an already constrained Federal budget. Therefore, it is critical to prepare for a pandemic crisis by developing, testing, and implementing proper mitigation strategies to lessen the magnitude of the impact of such a crisis on public health and the economy. For instance, Croteau (2006) stated that the estimated health burden of a future pandemic is estimated to be 79,000 to 207,000 deaths in the US with over $166 billion in economic loss.

2.2 Health Risk and Economic Burden from Influenza

Influenza represents a serious health risk and remains one of the major causes for morbidity, mortality, and disability in the U.S. population and worldwide. For instance, the CDC (2014) reported that in the U.S. on average five to 20% of the population (8.5% in 2013-2014 season) were infected with flu. Yearly, influenza also was accountable for 36,000 deaths and 200,000 hospitalizations from seasonal complications related to influenza. Initial surveillance data for the 2013-14 influenza season suggested general illness prevalence was much lower in comparison with the 2009 influenza pandemic (see Figure 2.1). However, the population of 18-64 year olds was at higher risk for complications from influenza this season (CDC, 2014).

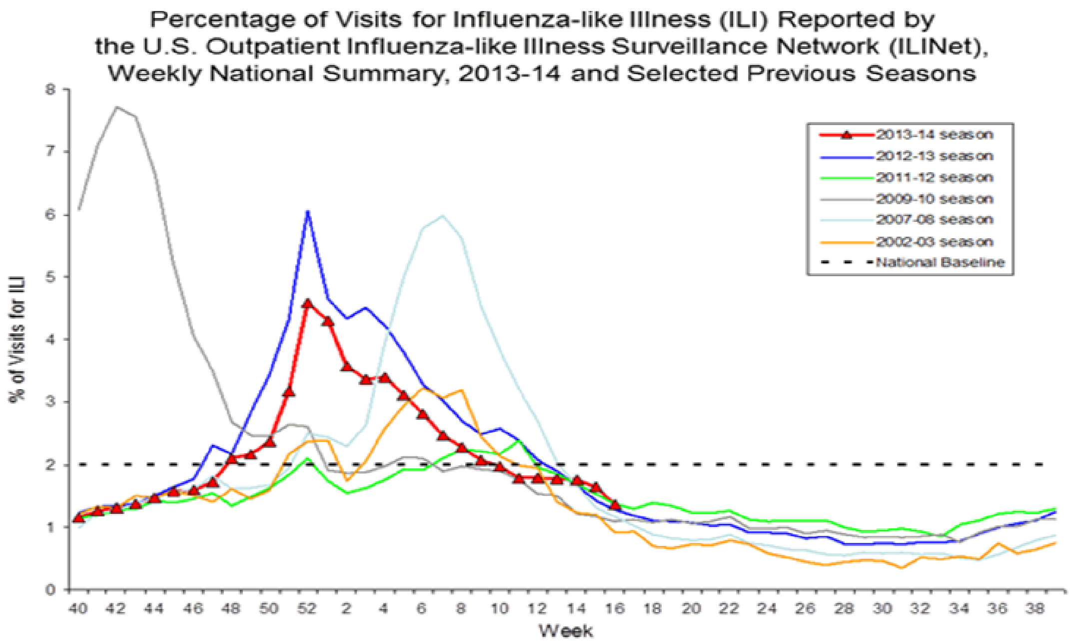

Figure 2.1. Percentage of Visits for Influenza-like Illness (ILI)

According to Anderson (2014), the economic burden of seasonal flu also is alarming, which puts at risk the country's security and disrupts the core spheres of its stability such as health, the economy and education. Seasonal influenza increases monetary expenses in families with school children and results in more school and work days lost. The author further noted that during the seasonal influenza period 20 to 40% of school-age children become ill with the flu. Many employers are alarmed by the cost of the disease spread in workplaces when employees exercise work presenteeism while being ill. For instance, a contagious employee infects 1.8 of every ten co-workers (Nichol, 2001). The estimated cost of lost work and school days is $37.5 billion and about $10 billion in medical expenses and lost productivity (Greenhouse, 2009). According to the CDC (2014), caregivers of children infected with influenza on average have medical expenses from $300 to $4,000 US dollars. Additionally, it was reported that caregivers of hospitalized children lost up to 73 work hours, which is equivalent to $1,456 (CDC, 2014).

Moreover, Greenhouse stated that the absence of paid sick leave policies increases the risk of rapid circulation of the virus during the flu season in workplaces and educational institutions. For instance, he noted that around 40% of all private business employees are not able to afford to stay home while being sick or if their children are ill. Single parent families are particularly sensitive to this dilemma, having only one bread winner in the household. Therefore, many working parents and particularly single-parents have to exploit the educational institutions as daycare facilities, sending contagious children to school and daycare, thus increasing risk of infectivity in educational institutions and society overall.

2.3 The Problem of Absenteeism

The Carnegie Foundation for Education (1990) reported that 83% of teachers believed that absenteeism due to infectious diseases has become a challenging problem that the educational system faces today. Neuzi, Hohlbein, and Zhu (2002) argued that about 75% of missed school days are attributed to illness, which impacts negatively on children's' learning processes, development, and economic outcomes. These authors also noted that the propagation of infectious diseases resulted in 164 million school days lost yearly among school children. Average school absenteeism constituted of 4.5 days missed for children and 5.3 days for teachers/year due to illness (Guinan et al., 2002; Hammond et al., 2000). The U.S. Centers for Disease Control (2014), reported that on average a school age child experiences four colds annually with each illness lasting from five to 14 days. Missed school days due to transmittable illnesses negatively impact on schools' administrative expenses, public funding, healthcare, and parental leave (Hammond et al., 2000).

Absenteeism has several detrimental consequences on the quality of life in society. Generally, absenteeism is defined as "an excusable or inexcusable absences from elementary or secondary school" (Kearney, 2008, p. 452). Excusable absenteeism relates to the days missed from school due to medical illnesses or injury. Inexcusable absenteeism is an academic absence associated with social, environmental, psychiatric, or other conditions (Kearney, 2008). Illness related absenteeism jeopardizes educational institutions and public health sectors in many detrimental ways. First, attendance is considered to be an extrapolative element of academic performance (White et al., 2003). Recurrent absenteeism disrupts students' learning processes and their overall academic progress and success; it also impacts their self-esteem and results in lower overall academic performance and tests scores (Vessey et al., 2007). Many scholars argued that numerous, brief absences are associated with repeated infectious diseases and are more adverse for the learning process than specific prolonged absences (Hezel et al., 2000; Vessey et al., 2007). Second, negative outcome of absenteeism is due to the fact that missed school days are linked to school funding. Funding for public schools is calculated on the basis of the attendance index and increased nonattendance results in decreased federal and state subsidy for academic programs (Vessey et al., 2007). Additionally, missed school days due to transmittable illnesses negatively impact on schools' administrative expenses, such as hiring substitutes and students tracking. Third, school absenteeism directly correlates with work absenteeism and lost productivity of employed parents, particularly during the flu season (Dietz et al., 2012). For instance, influenza accounts for 10% of all sickness absences of working parents. Moreover, school absenteeism has an overall negative effect on the functional status for a sick person or their caregivers. Reduced performance decreases reaction time and has adverse effects on health and safety at work (Szucs, 1999). Szucs (1999) stated that mild influenza reduces reaction times by 20%-40%. Overall detrimental effects on the quality of life of families with sick children include loss of leisure time and parental leave, inability to undertake normal daily activities, lack of rest time, fatigue, and extra healthcare expenditures (Hammond et al., 2000; Szucs, 1999).

According to the Center for Disease Control and Prevention (CDC, 2014), seasonal influenza epidemics occur annually, but it is still challenging for epidemiologists and virologists to predict every next flu season because its incidence, distribution, severity, place, and time depend on many factors. The CDC (2014) further noted that prediction also was difficult for the following reasons: type of virus, individual susceptibility, herd immunity, and effectiveness of preventative measures such as flu vaccine, antiviral prophylaxis, and proper hygienic methods.

2.4 Epidemiological Modeling

2.4.1 The Fundamentals: Infection, Transmission and Epidemiological Models

The focus of the field of epidemiology is to investigate how infections proliferate in a population. Infection is defined as "the invasion of one organism by a smaller (infecting) organism" (Vynnycky & White, 2010, p. 1). Infection is an ever-present and natural phenomenon. Many species of animals, plants and microorganisms carry various infections. Some of these infections are innocuous and even advantageous for organisms. For instance, bacteria that is present in human intestines is critical in digestion process. However, some infectious agents are capable of initiating diseases and are harmful for their hosts. Vynnycky and White (2010) postulated that infectious agents can be of various types, sizes, and shapes. For instance, influenza viruses are simple and small, and function as essential parasites of larger cells. However, bacteria are larger in shape and have more complex structures then viruses, and may grow autonomously.

Communicable agents may reside in the environment or animals, or they may live specifically in humans. Many infectious agents that live in animals and the environment may be transmitted to human hosts. For instance, at least 60% of infectious diseases nowadays are zoonoses (Peterson, 2002; Quammen, 2012). Zoonoses diseases refer to the diseases that transmit from wild or domesticated animals to humans. The transmission of zooneses occur due to the fact that ecological disruptions caused by humans are bringing animal pathogens ever more into contact with humans, while technology and human behavior elevate spreading of those pathogens. Ecological circumstances, high density populations, and travel mobility provide opportunity for transforming spillovers into pandemics (Quammen, 2012). Zoonotic diseases have pandemic potential and result from infection by pathogens including bacteria, viruses, worms, prions, protists, and fungi. The most bothersome pathogens are viruses, since they easily adapt to the host, are plentiful, and are hard to treat with antibiotics or antiviral drugs (Peterson, 2002; Quammen, 2012).

The transmission of an infection between animal or human hosts may occur via direct contact (e.g., leprosy), respiratory routes (e.g., influenza, tuberculosis), the fecal-oral route (e.g., dysentery, typhoid), sexual contact (e.g., HIV), vectors (e.g., malaria), or indirect contact (fomites) (e.g., influenza) (Vynnycky & White, 2010). After penetrating into a human host, the infectious agents reproduce for a period of time and then are able to cause a disease or be transmitted to other individuals. Different infections may have various outcomes. Thus, some infections may be mild and result in little illness in the host and some may be extremely deadly. The duration of illness depends on the ability of the infectious individual to produce an immune response. Immune refers to an individual "who has complete protection to an infection, which results either from vaccination or previous infection" (Vynnycky & White, 2010, p. xxiii). There are three main types of immunity to an infection sturdy immunity (individuals are completely protected from an infection); partial immunity (individuals may be free from an infection, but continue to be susceptible to recurring contamination), and little or no immunity (individuals are able to be infected and be infectious permanently).

2.4.2 Historical Perspective on Epidemic Modeling

Infectious diseases have been the leading cause for morbidity, mortality, and disability of human population throughout the recorded history of human civilization. For instance, various infections such as bubonic plague, influenza, smallpox, measles, and diphtheria caused devastating pandemics and epidemics that drastically reduced human population. Many scientists endeavored to understand how communicable diseases spread in a population in order to control, prevent, and predict such diseases to save lives.

John Graunt (1620 -1674) was the first scientist who attempted to measure the reasons of mortality (Black et al., 2013). He believed that the reasons for mortality and morbidity could be explained via "laws of mortality," which could be deducted by monitoring illness and death patterns among humans, patters expressed in terms of mathematical relationships (Aschengrau & Seage III, 2008). According to Black (2013), Graunt systematically recorded and analyzed morbidity and mortality data and examined the relationship between demographic variables and mortality rates. Graunt also calculated life tables and life expectancy measure. He became the first statistician, demographer, and epidemiologist after developing the Bills of Mortality, where he listed possible causes of death during the Black Plague, which occurred from 1347 – 1350 (Black, 2013).

2.4.3 Modeling

According to Daley and Gani (2005) the means by which an infection spreads can be observed through modeling of infectious diseases. This tool is employed to study and forecast the courses of an infection and to assess the effect of certain methods of prevention and control intervention on the disease course.

Modeling refers to the method of resolving problems, where a studied system is substituted by the simple entity that represents the behavior of the real system, identified as a model (Borshev, 2013). Vynnycky and White (2010) defined a model "as a simplified representation of a complex phenomenon" (p. 8). Modeling is employed when experiments with a real system are dangerous and unfeasible, due to the expensiveness of testing and prototyping, length of experiment in real time, and ethical issues. Additionally, modeling enables optimization of a system before implementation (Borshev, 2013; Kirby et al., 2012; Merkuryeva and Bolshakov, 2010).

Therefore, the modeler builds a representation of a system in a modeling language. Borshev (2013) advocated that modeling incorporates several processes. The first process comprises projecting the real world scenario problem onto its simplified representation (chosen type of model). The second process includes mapping the explanation back onto the studied problem. The model is flexible, allowing changes and being less complex than the original system. There are various types of models used in modeling: mental models, logic models, boxes and lines, physical models, and formulas.

Modeling is a proper tool to investigate infectious diseases in humans, since communicable diseases is a complex phenomenon, and since research involving human subjects is difficult, expensive, and raises serious ethical issues. The transmission of infectious diseases can be investigated via modeling, which can focus on progressively larger scales and fluctuate from localized units (outbreaks), communities and cities (epidemic), or global (pandemic) scales (Dietz et al., 2012). Various types of diseases including respiratory, vector-borne, airborne, food-borne, waterborne, and sexually transmitted are mostly modeled ones (Vynnycky & White, 2010). Modeling of communicable diseases enables a researcher to comprehend the means of disease transmission and ascertain the best methods to control and prevent them from excessive proliferation. Outbreak or epidemic modeling is the proper approach for testing different prevention and control measures.

2.5 Types of Models

Epidemic modeling of human infectious diseases has a long history and encompasses four main types of models: animal models, mathematical models, mechanical models, and computer simulation models.

2.5.1 Animal Models

According to Vynnycky and White (2010), animal models were very popular in the beginning of the 20th century and involved the population of mice, to whom various infections were introduced. However, this modeling method was very costly and now is hardly employed.

2.5.2 Mathematical Models

The next type of infectious disease models are mathematical models. According to Vynnycky and White (2010), these models employ population parameters, which are represented by symbols and connected by formulas. It was Daniel Bernoulli who in 1766 first employed mathematical modeling to examine the proliferation of infectious diseases (Hethcote, 2000). Bernoulli, who was a physician, developed a model built on differential equations to measure the efficacy of vaccination method from smallpox. His model revealed and supported the hypothesis that overall vaccination against smallpox would improve life expectancy (Bernoulli & Blower, 2004).

The next contributors to mathematical epidemiology were A.G. Kendrick and W.O. Kermack, who in 1927 created a compartmental (deterministic) model to predict the behavior of outbreaks and epidemics (Epstien, 2009). Their susceptible-infected-recovered (SIR) model presumed that the population was static and had only three phases: susceptible S (t); infected I (t); and removed R (t): $N = S(t) + I(t) + R(t)$. The description of these phases appears in the Table 2.1

Table 2.1
Description of the SIR Model Variables

Variables	Definition
S (t)	denotes the individuals who have not yet contracted the infection at time t, and who are at risk from the disease.
I (t)	represents infected individuals who developed the infection and are able to spread it to susceptible individuals.
R (t)	signifies infected individuals who were later removed from the disease course due to death or immunization. The individuals in this phase are not capable of transmitting the disease to others or infecting others.

Figure 2.2. Flow Diagram of SIR Model

The flow of Kermack and Kendrick's model is represented in Figure 2.2. The SIR model assumes that the infectious individual is capable of infecting others immediately upon contact. However, many infections have an incubation (latent) period, which is considered to be an exposed phase (Vynnycky & White, 2010). During this phase, an individual is infectious, but does not reveal any symptoms.

The model of infectious diseases with latent periods comprises four phases: susceptible S (t), E (t)exposed, infected I (t), and removed R (t). According to this model, the population N equals to the total of these four stages: N = S (t) + E (t)+ I (t) + R (t) (Arino et al., 2006). The flow diagram of the susceptible-exposed-infected-removed (SEIR) model can be viewed in Figure 2.3.

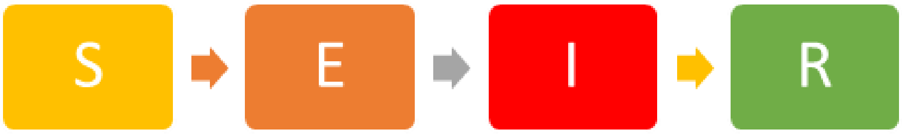

Figure 2.3. Flow Diagram of SEIR Model

The above-mentioned compartmental models are used by epidemiologists to measure the effects of control and prevention interventions on various infections. However, mathematical models have many limitations that prevent epidemiologists from obtaining more precise results on the efficacy of various intervention methods on a disease's course. For instance, these models presuppose that the studied population is ideally mixed and that individuals are moving from the susceptible stage to the infected stage and later to the removed pool (Epstein, 2009). Furthermore, within these pools, everyone is identical and no one adopts their behaviors. Even though mathematical models are capable of quantifying and measuring the threshold of epidemics and elucidate herd immunity, such models are unsuitable for evaluating complex social systems and direct contact between individuals, who in real life modify their behaviors depending on disease prevalence (Epstein, 2009).

2.5.3 Mechanical Models

Mechanical models were designed at Johns Hopkins University to measure the probability of disease spread in populations (Vynnycky & White, 2010). At the beginning, the mechanical models were built using beads of various colors, that were placed in special trays and were very difficult to operate. However, mechanical models were improved and widely adopted with the use of computers, particularly in computer simulation experiments. Computational infection spread models have broadened the research launched by mathematical models and have addressed many limitations of other modeling approaches.

2.5.4 Computer Simulation Models

With the rapid development of information technology, the computer models became a novel analytical tool and are widely used in modeling. The novel information technology methods, particularly epidemiological computer simulation models, were designed to comprehend the dynamics of contagious disease propagation and to analyze the effectiveness of the mitigation strategies advised in pandemic preparedness plans (Chao et al., 2010; Dietz et al., 2012; Emrich et al.,2007; Halder et al., 2010; Skvortsov et al., 2007). Simulation modeling is a computational tool used to design, test, and study behaviors of real world scenarios in a virtual setting and to theorize results (Dragoul et al., 2008). The outcomes of this innovative information technology enable scientists and key stakeholders to determine and measure the effectiveness of certain intervention strategies that might reduce annual influenza epidemics, and lessen the initial waves of future pandemic influenza in an ethical, timely, and cost-effective manner. Simulation modeling procedures used for respiratory infectious diseases comprise stochastic, deterministic, and agent-based models (Halder et al., 2010; Skvortsov et al., 2007).

Borshev (2013) stated that the spreadsheet is mostly accessible and used as a modeling software to model and solve mathematical problems. For instance, MS

Excel is based on the spreadsheet principle modeling. Further, he postulated that spreadsheets are limited to finding only static relationships among the variables and fail to represent systems with dynamic behavior. Therefore, simulation modeling approach was particularly designed to examine dynamic structures and relationships within them. Simulation modeling technology is appropriate when a model has too many parameters and is too complex for other resources (e.g., uncertainty, nonlinear and illogical behaviors, periodic and two-way dependencies).

Simulations refer to a particular category of computer models that are based on mathematical models. The behavior of such models are based on data, determined by algorithms and equations, and denoted by certain types of computer interface (Borshev, 2013). These models imitate real-world systems behaviors and provide the theoretical solutions based on input data. Borshev and Fillipov (2004) define simulation as “the process of model execution that takes the model through (discrete or continuous) state changes over time” (p. 1). Simulation modeling allows the user to analyze and assess complex problems with dynamic activities faster and less expensively than physical systems.

Simulation modeling is a novel methodology that is used in a variety of disciplines. It is becoming an alternative approach to lab and field experiments (Sekeran & Bougie, 2009). Simulation embraces a model-building approach to ascertain the impacts of changes. According to Sekaran and Bougie (2009), a simulation can be viewed as an experiment performed in a particularly created environment that closely imitates the natural environment where various activities are carried out. Participants in the simulation experiments are subjected to real world scenarios where they can be randomly assigned to various interventions over a period of time.

Borshev (2013) postulated that modern simulation modeling encompasses three main types of modeling methods, each of them supporting a certain level of abstraction. Thus, system dynamics (SD) functions at high levels of abstraction and is employed in modeling for strategic purposes. The discrete event (DE) approach operates at medium and medium-low abstraction levels and is used in tactic modeling. The agent based (AB) method may vary between high, medium, and low levels, depending on the simulation scenario and defined details (Borshev, 2013).

2.6 Epidemiological Model Set Up

In order to develop an epidemiological model that mimics the spread of infectious disease, several steps should be taken. Vynnycky and White (2010) stated that this process comprises several critical phases: identifying the problem, determining key features about the infection in this problem, selecting the modeling method, identifying input parameters of the model, building the model, validating the model, and optimizing the model. Figure 2.4. depicts the steps that might be employed to build a model representing the propagation of an infectious disease.

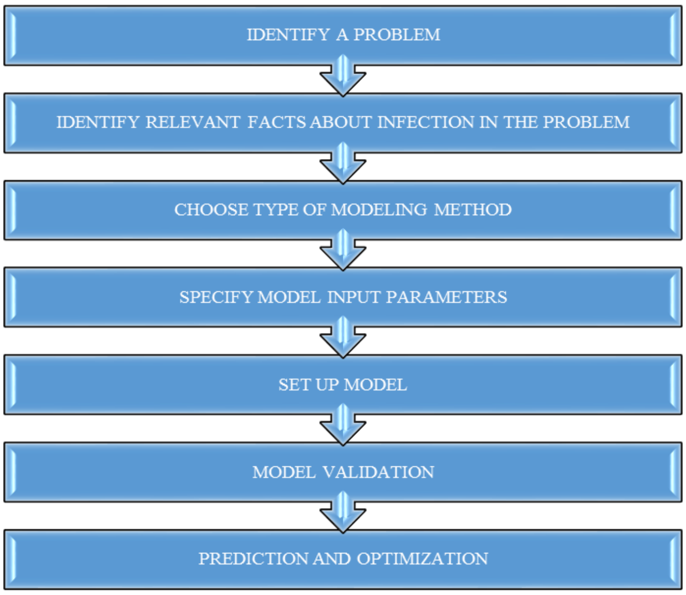

Figure 2.4. Phases in Creating an Infectious Disease Spread Model

2.6.1 Determining Key Features about the Infection in the Modeled Problem

Epidemiological models begin with a simple description of the subject under study and next describe essential elements that determine real-life behaviors. These simplification and logic steps are critical for determining the outcome of a modeled scenario. It is essential to begin the process of modeling an infectious disease by determining key epidemiological features of that infection. These features may include identifying the subclinical phase of the infectious disease. This phase lasts from exposure to infection to onset of the symptoms and is called an incubation period for the infectious diseases; and latent period for chronic diseases (Black, 2013). During the incubation period, an individual reveals no symptoms. The incubation period for various infectious diseases is different. The next step is to identify how long an individual is contagious and determine what age groups are mostly affected by this disease.

2.6.2 Selecting the Model Structure

According to Black (2014), while modeling infectious disease propagation, three main factors should be considered: the research question of the modeled scenario, the dynamic of the disease transmission, and natural history of the disease; and the time period over which this disease spreads in the modeled scenario. In order to protect, prevent, and control any given disease, it is essential to understand the etiology, dynamics, distribution, and factors impacting disease spread to apply proper control and prevention measures. Human diseases do not occur in isolation or at random, but rather are impacted by the surrounding environment.

2.6.2.1. The Dynamic of Disease Transmission and Natural History of Disease

Gordis (2009) postulated that any disease is an outcome of an interaction of the host (e.g., an individual), the agent (e.g., virus), and the environment (e.g., fomites) (see Figure 2.5).

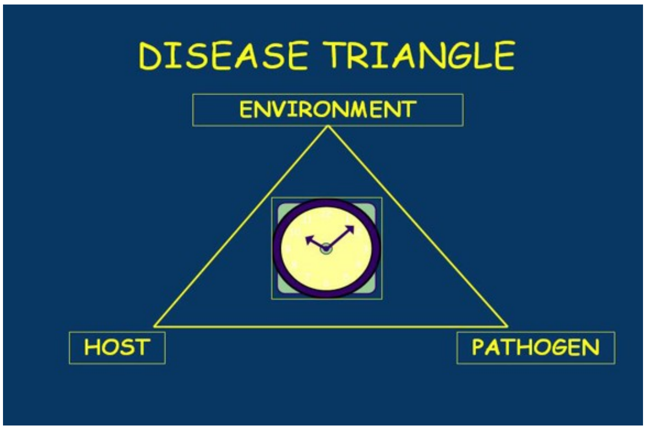

Figure 2.5. The Epidemiologic Triangle of a Disease

The agent triggers the infection and is considered to be the "what" of the disease triangle. The host (the "who" of the triangle) is the organism that harbors the infection. Finally, the environment (the "where") comprises the external factors that contribute to the disease spread (CDC, 2014). Gordis (2009) further noted that these factors causing human disease include physical, biological, chemical, or stress-related factors. Further, he argued that any diseases can be transmitted directly (person-to-person) and indirectly (common vehicle, vector) and undergo a natural history of the disease. "The natural history of the disease is defined as the course of the disease from its inception to its resolution" (Aschengrau & Seage, 2008, p. 412). According to the CDC (2014), the disease course starts with exposure to several factors necessary for disease propagation in a susceptible host (see Figure 2.6.).

According to CDC (2014), the susceptible individual ordinarily does not have immunity (acquired or natural) and will contract the disease. Infectious disease occurs due to exposure to a microorganism. Pathological changes occur in the subclinical phase once the disease process is triggered and at this stage the individual is unaware of them (no symptoms). This stage of disease course expands from the time of exposure until the onset of disease symptoms and is called the incubation period for infectious diseases or latent period for chronic diseases.

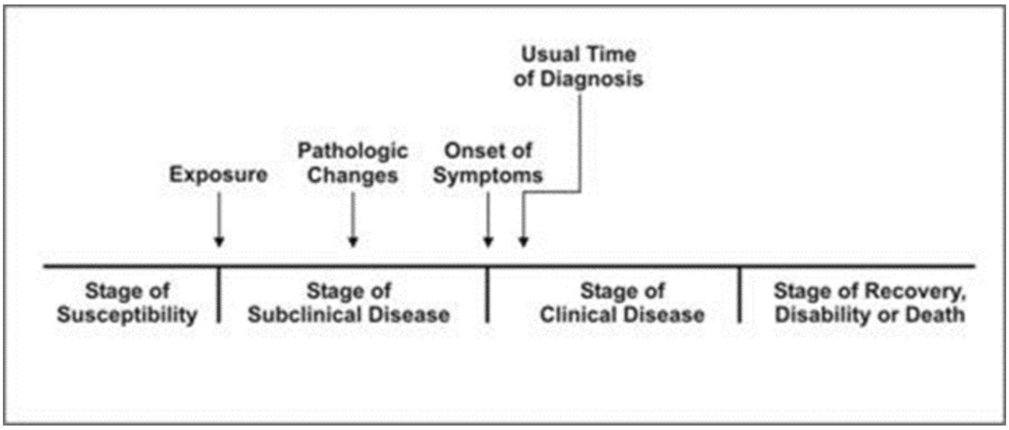

Figure 2.6. Natural History of Disease

The clinical disease stage takes place from the onset of the first symptoms until the end of the disease. Treatment should start when a diagnosis is made. The clinical stage may be followed by recovery, disability, or death, and depends on the type of disease and whether a cure exists. According to Aschengrau and Seage III (2008), the disease progression for individuals on each phase of the disease course is specific; different people progress quickly or slowly. Further, they noted that though diseases undergo a natural history, their specific characteristics and length vary individually and depend on therapeutic or preventive measures.

Gordis (2009) advocated that in order to investigate an occurrence of a disease that exceeds an epidemic level, it is critical to examine its distribution. Disease distribution is defined as the investigation of the patterns of a disease in regards to attributes such as person, place, and time (Aschengrau & Seage III, 2008). These attributes refer to: who is getting a disease (e.g., demographic variables: age, race, sex, socio-economic; marital status); where it is occurring (place variable: a specific geographical location); and how it is changing over time (time variable: a specific time; seasonal pattern; Black, 2013).

2.6.3 Choosing a Modeling Method

Epidemiological models that represent communicable diseases' transmission are classified as stochastic or deterministic (Epstein, 2009; Vynnycky & White, 2010). According to Vynnycky and White (2010), stochastic models reflect what happens to individuals when they transfer among compartments at random. Compartments in such models denote subgroups such as susceptible, exposed, infectious, or recovered. For instance, the rate at which individuals can be infected or recovered are best determined by stochastic models. Further, the authors noted that deterministic models represent what occurs to individuals in a population during the disease course "on average." In such models, the input parameters are fixed and the outcomes of the modeled infection are predetermined.

2.6.4 Classification of Epidemiological Models

Vynnycky and White (2010) argued that division of epidemiological models into just two broad categories, such as stochastic and deterministic, is too simplistic. The authors further asserted that both model types may include several elements that are typical to a certain modeling type and can be further classified into compartmental, microsimulation or individual-based, transmission dynamic, static, and network models.

For instance, compartmental models trace the infection spread among individuals in the subgroups (compartments) jointly. These models may be whether deterministic or stochastic. The microsimulation or individual-based models trace the spread of the infection for every person in the given population and usually are stochastic. The transmission dynamic models reflect the transmission of the modeled infection among individuals upon contact. In such models, the number of contagious individuals changes over time, depending on such variables as the number of contagious individuals in the given population and the likelihood of being infected. Static models do not define contact among people and the probability of infection transmission is predetermined. According to Vynnycky and White (2010), such models are ill-suited to measure the efficacy of intervention of the infection spread in a given population. The network models describe the contacts among individuals in the network. The probability of infection transmission in such models depends on the individual to whom other people are linked. The network models are widely used to model the transmission of infections in the populations.

2.7 Agent-Based Modeling Approach

Computational infection transmission models are novel types of models that encompass various features of the traditional epidemiological models. These types of models supported the research commenced by mathematical models and also conveyed the limitations of them. Computational infection-spread models are best represented via agent-based method (Borshev, 2013; Dietz et al., 2012; Epstein, 2009). The primary advantage of agent-based models (ABM) over other modeling methods is their capability to simulate contact among individuals, which is the key means for infection spread. Furthermore, agent-based simulation models allow scientist to implement control measures into the model and measure their efficacy on disease spread (Chao et al., 2010; Dietz et al., 2012; Epsein, 2009). Additionally, agent-based models are best suited to simulate stochastic implications that reflect and quantify heterogeneous behaviors in populations (Borshev, 2013). Consequently, agent-based models considerably contribute to better comprehension of infectious disease proliferation, both its control and prevention.

Agent-based simulation is a novel system to model heterogeneous systems (Borshev, 2013). Agent-based models are software-demonstration arrangements comprising discrete small units (agents). These models show collection interrelating and modifying through discrete time intervals, which grow into macrosystems (Barbati et al., 2012; Macal & North, 2010). The main purposes of all agent-based simulation models are to expend and assess theoretical assumptions (Auchincloss &

Dietz Roux, 2008). Agent-based simulation modeling was inspired by artificial life, social interaction, and genetic mutation theories (Macal, 2010).

Borshev (2013) asserted that ABM is a more recent modeling paradigm than DE and SD. Further he stated that ABM modeling was basically a theoretical topic until the 2000s. The simulation experts adapted AB modeling in 2002. There were several reasons behind ABM implementation. First, there was a need to identify the insight behavior of the system that could not be recognized by traditional modeling frameworks. Second, the innovations in computer science, particularly object oriented modeling, statecharts, unified modeling language (UML), availability of central processing unit power (CPU), and memory, advanced the employment of ABM (Borshev, 2013). Thus, the above-mentioned computer information technology innovations enable simulation modelers to build the model from the "bottom-up" level in order to examine and define the individual behaviors of the objects (agents) and their mutual interactions and adaptions. Such interactions emerge from microscale and evolve into the macroscale, providing a theoretical link amongst the macro and micro levels (Auchincloss & Dietz Roux, 2008).

Borshev (2013) stated that AB modeling does not have a standard language and that ABM is built using scripts or graphical editors. Bonabeau (2002) advocated that ABM is a tactic rather than a technology. Further, he noted that AB modeling describes a system from its constituent entities standpoint and is synonymous with microscopic modeling. ABMs were employed by simulation practitioners to investigate complex systems, artificial life (Alife), and complex adaptive systems (Begnati et al., 2002). According to Bonabeau (2002), a system modeled with the AB method represents a collection of autonomous decision-making agents. Further, he stated that each entity (agent) evaluates its situation and generates a decision specified by a set of rules. Depending on the modeled scenario, agents in the AB model are capable of performing various behaviors in a complex system. For instance, agents might infect, manufacture, consume, retail, etc. Bonabeau (2002) showed that a distinctive feature of AB modeling is the recurrent competitive interaction among agents. Further he asserted that AB modeling has other unique advantages over other simulation approaches: it seizes emergent phenomena, represents the system close to reality, and is flexible.

Emergent phenomena, in ABM simulation, occurs from the agent's interactions, behavior modifications, and reactions and it evolves from bottom up. For instance, a small modification in an agent's behavior may dramatically effect the whole group's collective behavior (emergent phenomenon). ABM is an appropriate method to predict evolving collecting behavior and to deal with complex individual behaviors such as adaptation and learning (Bonabeau, 2002). This method is suitable to employ when there are prerequisites for emergent phenomenon such as agents' behavior being defined by limits, if-then guidelines, or nonlinear connections. Furthermore, emergent phenomenon arises when agent's behavior reveals memory, path-dependence, and heterogeneity, which makes it possible to generate a network.

ABM describes complex systems more realistically than the SD and DE methods. It is particularly useful for the problems that involve diverse actors interacting in various ways. Bonabeau (2002) stated that AB modeling is a proper method to use when individual and collective behaviors of agents are difficult to define with differential equations or via aggregate transition rates due to complexity of activities. ABM is a single approach that enables a user to mimic the system's environment, examine the collective properties, and analyze activities in process within the studied system. Another benefit of ABM over other simulation methods is its flexibility. For instance, a modeler can easily introduce more agents to the agent-based model. Furthermore, AB method enables a user to modify the agents' intricacy by adjusting agents' behavior and rationality, patterns of interactions, and capacity to learn and adapt. Additionally, ABM allows for adjusting the levels of agents' aggregation (groups or single agents) and complexity.

2.7.1 Structure of Agent-Based Models

The basics of creating an agent-based model include defining the object of simulation and the population of agents and identifying the agent's adaptive and interactive (cooperative or competitive) features (Macal & North, 2010). The primary step in creating an ABM is to specify the problem that has to be studied and replicated and to determine the space where the simulation experiment occurs. Typically, a classic ABM comprises the following components: a group of agents with their behaviors and characteristics, methods of agent's interaction and a collection of agent's links, and the environment of agents (Macal & North, 2010). A simulation modeling tool supporting the agent-based approach is needed to build an agent-based model. To run the ABM means to make agents recurrently perform their interactions and activities.

2.7.2 Agents and Agents' Characteristics

Bonabeau (2002) explains that the first critical component of an agent-based model is a set of entities (agents). These small entities (agents) can be represented by anything that changes their actions from other agents and the surroundings. There is no unique definition of an agent, as it is determined by the purpose of the simulation. Heath at al. (2011) defined an agent as "a modular, self-contained, and uniquely identifiable individual" (p. 2791). Further, he stated that this prerequisite entails an agent to have boundaries. Every agent is self-directed and independent, which allows it to function autonomously, while intercepting with other agents in the environment. An agent's behaviors are defined by algorithms and represented by simple predetermined parameters and a "stimulus-response frame" (Heath et al., 2011, p. 2791). The author also noted that in agent-based simulation the agent is a social unit that interacts via predefined networks.

Agents can have several attributes in ABM that enable other agents to identify and differentiate them. An agent's attributes may be static or dynamic during a simulation experiment. For instance, a characteristic such as the agent's name is constant, while the agent's memory of its interactions is changeable. The agent's possible qualities and their definitions are represented in Table 2.1.

Agents in agent-based models do not always contain all the above-mentioned features. However, the most important qualities of an agent in ABM are its autonomy, adaptiveness, and heterogeneity. The autonomy feature is possible due to the fact that agents are endowed with behaviors that enable them to act proactively and freely in their environment and intermingle with various agents. Furthermore, agents' individual behaviors and attributes allow the modeler to observe and analyze the impact of these qualities on the whole system's emergent behavior.

An agent's behavior links information identified by the agent to its activities and decisions. Such information arrives via the agent's interactions with its environment or other agents. The behavior of an agent is stipulated by simple rules or conceptual models (e.g., artificial neutral networks [ANN]), where agents' inputs are linked to outputs via adaptive means (Macal & North, 2010). Thus, often the agent possesses a state or a notion that changes over time. An agent's state comprises a set of characteristics that are associated with its status or a position the agent holds. According to Macal & North (2010), a state of an ABM "is the collective states of all the agents along with the state of the environment" (p. 153). Further, the authors noted that the actions and reactions of an agent are stipulated by its state, and the more the agents set of states, the more behaviors the agent has. Additionally, the state makes it possible to relocate the system from the current location forward.

The states of an agent are best described by statecharts. According to Borshev (2013), "a statechart (an extended version of a state diagram) is a visual construct that enables you to define event-and time-driven behavior of objects" (p. 287). Further, he stated that a statechart can be viewed as an object's clustered history and reactions to outside activities that determine that entity's future events. Usually statecharts are comprised of states and transitions. Thus, the response of an agent in a certain state is determined by transitions leaving that state. For instance, transitions in agent-based models may be triggered via conditions, certain messages, timeouts, or arrivals.

2.7.3 Agents' Interactions

The second essential component of an agent-based model is the agent's interactivity. Agents' interactions and relationships determine agents' behaviors in ABM. It is essential to specify to whom agents could be connected and to clarify the means of agents' interaction while modeling their relationships. Macal and North (2010) stated that agent-based systems are dispersed and that there is no dominant governance that controls agents' behaviors or forwards information to the agents. The interaction of agents in ABM mimics the contacts that occur in real-world systems. Thus, while interacting with each other, agents do not interact directly with each and every agent from the entire agents' population all time. Typically, agents obtain their information only through interactions with its immediate neighbors and local environment (Bonabeau, 2002; Macal & North, 2010). An agent's neighbors change quickly during a simulation experiment. Agents are linked to each other via networks of nodes (agents) and links (agents' contacts; Borshev, 2013; Macal & North, 2010). These topologies define which agent passes on the information to other agent. Depending on the modeling scenario, agents may interact through several topologies (e.g., passing infection).

2.7.4 Agent's Environment

The third key component of an agent-based model is the agent's environment. The interaction of agents occur within the environment they inhabit. The environment reveals the position of the agent in regards to the other agents coexisting within this environment. Furthermore, the environment may limit agent's activities. According to Macal and North (2010), the information on agents location is essential to tracing agents' movements, resources, and space attainment, and dealing with other situations in the modeled environment.

2.8 Specification of Model Input Parameters

2.8.1 Clinical Features of Influenza

Influenza (generally identified as flu) is a highly contagious infectious disease caused by the influenza single-stranded RNA virus. The term "influenza" originated in the 15th century in Italy from an epidemic ascribed to the "influence of the stars" (CDC, 2014). According to Quammen (2012), RNA viruses are the most troublesome to prevent and control as they are pliable, prolific, and resistant to antibiotics and antiviral drugs. He further stated that RNA viruses quickly reproduce and generate acute infections; acute infections are characterized by viral shedding via coughing, sneezing, vomiting, diarrhea, or bleeding, which makes them highly virulent, contagious, and hard to prevent and control.

According to Heymann (2008), the main antigen types A, B, and C are identified by their nuclear material. He further stated that influenza A causes moderate to severe illnesses among all age groups, infecting humans and animals. He also noted that influenza type B affects mostly children, causing milder illness than influenza type A, while type C virus is an uncommon cause of illness among humans. Seasonal influenza occurs in the period between November and May (it usually peaks in February CDC, 2014). Influenza is a respiratory illness with a short incubation period, usually from two to four days, and propagates via large aerosol droplets (>5mm), expelled by coughing and sneezing and then inhaled (Heymann, 2008). The author noted that droplets can travel through the air from three to six feet from the source. In adults, viral shedding and probable communicability occur three to five days before the onset of symptoms.

Epidemiologic studies suggested that natural history of the influenza virus is different for children in comparison with adults (Hsieh et al., 2014). Thus, children shed viruses up to six days before the illness starts and for 14 days once they are infected (Heymann, 2008; Lewin, 2012). According to Hsieh et al. (2014), the clinical symptoms of influenza include headache, fever, running nose, sore throat, cough, fatigue, vomiting, diarrhea, and muscle or body ache. The authors further stated that clinical symptoms for infected schoolchildren also may include signs of nausea and otitis media. However, some flu-infected individuals, especially children, may be carriers (Heymann, 2008). Carrier refers to an individual who sheds an infectious agent but does not have any clinical symptoms (Vynnycky & Wight, 2010). For instance, the asymptomatic (carriers) ratio for the schoolchildren is from 55.6% to 77.9% (Hsieh et al., 2014).

2.8.2 School Children are Centrifuges of Influenza

School age children are the major centrifuges of influenza, who have the highest attack rates with short (two day) incubation periods and are likely to be asymptomatic (Heymann, 2008; Lewin, 2012; Mikolajczyk et al., 2008). Attack rate is defined as "cumulative incidence of infection or disease in a group of people observed over time during an outbreak or epidemic" (Glatman-Freedman et al., 2012, p. 2). Cauchemez et al. (2008) stated that children are responsible for more than 46% of all infections in the population. Moreover, during the 2009 flu pandemic, the initial diagnosed cases were detected in households and educational settings, with over 50% in school-age children (Heymann, 2008). Being in close proximity to peers and family, school-age children typically do not follow cough-and-sneeze etiquette or hand hygiene.

Additionally, they have higher contact rates/day: 25.1 in comparison to 7.5 for adults (Mikolajczyk et al., 2008). These authors also stated that the effective contact rate among young children is 1.9 and that the probability of transmission of disease/contact among children consisted of 0.5. The fact that higher attack rates from the influenza virus occur among school children suggested that this specific group is the host of influenza virus (Glatman-Freedman et al., 2012). Additionally, these authors noted that the physical environment within crowded schools is another factor of influenza transmission among school children and the population in general.

2.8.3 Mode of Transmission

Influenza transmission occur either directly or indirectly. Direct is contact between infected and susceptible individuals. Indirect contact happens when pathogens are transmitted via an intermediate source, such as contaminated surfaces (fomites; Black et al., 2013). For instance, influenza A and B viruses survive on nonporous dry surfaces such as plastic and stainless steel for 24 to 48 hours; and on porous (e.g., paper, cloth, tissue) less than 12 hours. Infected individuals are able to transmit the virus via nonporous fomites for two to eight hours. Influenza A and B viruses survive on hands up to five minutes after transfer (Black et al., 2013). On average people touch their face about 15.7 times per hour, which is more than every four minutes. The virus transmission from contaminated hands to fomites and from fomites to hands, then to mouth, eyes, and nose was confirmed in several studies (Bright et al., 2010; Guinan et al., 2002; Luby et al., 2005). The impact of such cross contamination results in higher incidence rates among populations, particularly schoolchildren.

2.8.4 Influenza Control and Prevention Methods

Infectious diseases that cannot be eradicated can be controlled via use of vaccination, antiviral drugs, and proper hand hygiene (CDC, 2014). Vaccination is considered to be the primary control method for influenza. Thus, the annual vaccination coverage threshold for herd immunity against influenza should be 80% for healthy individuals and 90% for at-risk groups and health personnel

(Plans-Rubio, 2012). According to Gordis (2009), herd immunity refers to "the resistance of a group of people to an attack by a disease to which the large proportion of the members of the group are immune" (p. 24). However, annual flu vaccination coverage is still insufficient to maintain immunocompetence of the population to resist the disease. Flu vaccination coverage for children five to 12 years old for the 2012-2013 flu season consisted of only 58.6% (CDC, 2013). Moreover, vaccination is a costly method and more likely to be unavailable in adequate quantities in times of crisis. For instance, Longini et al. (2004) stated that in case of novel flu strain virus emergence it would take up to eight months to identify, produce, and distribute a corresponding vaccine. Additionally, the current manufactured vaccine capacities are enough to vaccinate only 14% of world's population within a pandemic year (Stebbins et al., 2011).

Longini et al. (2004) postulated that the use of antiviral drugs such as oseltamivir, amantadine, rimantadine, and zanamivir are considered to be another effective strategy to lessen flu epidemics and slow the first wave of an influenza pandemic. However, they acknowledged that these antiviral drugs have various efficacy spectrums on the various stages of the virus life cycle. For instance, amantadine and rimantadine are only effective as a therapeutic method, whereas oseltamivir and zanamivir tend to be effective as prophylactic methods (Longini, 2004). Other effective influenza intervention methods include nonparmaceutical measures: hand washing with soap; disinfecting workplace surfaces; maintaining social distancing (three to six feet); incorporating respiratory etiquette; travel restrictions, quarantine; reducing the number of social gatherings; using N95 respirators and masks; and school closures (CDC, 2013; Ingelsby, 2006). Fresh air ventilation also is an effective and inexpensive intervention in battling airborne diseases propagation in crowded facilities (Liao et. al., 2005). According to the CDC (2014), amalgamation of nonpharamaceutical interventions can be effective in slowing the spread of the flu during initial phases of a pandemic.

It is often problematic to choose an intervention procedure to implement when several exist. According to WHO (2009), decisions regarding intervention depends on whether they reduce morbidity, disability, or mortality and whether they improve quality of life. According to WHO (2009) guidelines, such decisions have to be based on the one that provides better return on investments. This is particularly the case when public health resources are limited, as in 2015; a decision has to be made in favor of the methods that are economical and that efficiently reduce mortality, morbidity, and disability. According to CDC (2014), hand hygiene is the only intervention that corresponds to the above-mentioned criteria. Furthermore, it is recommended and proven to be a simple, effective, and low-cost non-pharmaceutical intervention to reduce influenza propagation. For example, it was implemented during the 2009 H1N1 flu pandemic by local, sate, and global health organizations, which enabled to control and prevent vast flu proliferation (WHO, 2009).

Prevention of respiratory infections such as influenza is the most effective way to reduce cost and illness-related absenteeism in the society. According to Bright (2010), hands contaminated with microorganisms are the prime mode of infectious diseases propagation, cross-contamination, and secondary infection in close educational environment. Maintaining proper hand hygiene, which is a primary preventative measure, is considered to be a critical method according to the CDC in preventing and controlling the transmission of communicable diseases in populations.

2.9 Effects of Hand Washing Intervention on Pathogens

According to WHO (2008), hand washing with soap is the single economical control and preventative method. WHO used the disability-adjusted life-years measurement to evaluate the impact of health interventions on diarrheal diseases, combining data on years lived with disability and years of life lost (YLL). As a result, the organization reported that hand washing with soap was the most economical method (costing $3.35) to avert disability-adjusted life years related to diarrheal diseases (WHO, 2008).

Furthermore, the CDC (2014) advocated that hand washing with soap is a simple and effective method of controlling and mitigating the circulation of influenza virus during flu season. Hand washing with soap also prevents skin and eye infections and intestinal worms, Avian Flu, and SARS, and advantages people with HIV/AIDS (WHO, 2008). For instance, it was estimated by WHO (2008) that hand washing with soap is able to prevent more than 3.5 million pediatric mortalities ever year due to diseases caused by contaminated hands. Additionally, evidence suggested that improved hand hygiene practices with soap reduce the infection rate by 25%, respiratory infections by 23%, pneumonia-associated infections by 50%, and diarrheas by 47% among children (Curtis & Cairncross, 2003; WHO 2008). Hand washing with soap also is an effective means of preventing diseases spread by fecal-oral route, such as worm infections, cholera, and typhoid. For instance, Mead et al. (1999) found that failing to wash or not washing hands properly contributes to 50% of all foodborne illnesses outbreaks. Other research by Curtis and Cairncross (2003) indicated that hand washing with soap decreases diarrheal illnesses by 40% and could save up to one million lives annually.

The positive impact of hand washing programs on reducing illness rates and absenteeism among elementary school children was evaluated in several studies. Thus, several experimental hand washing programs incorporated in elementary schools translated to decreased absenteeism due to infectious illnesses (Guinan et al., 2002; Hammond et al, 2000). Rabie and Curtis (2005) stated that hand washing reduces the respiratory infections by 16%. According to Aiello et al. (2008), hand washing practices reduced the risk of respiratory infections by 21%.

Implementing experimental educational programs on hand hygiene combined with accessible and convenient facilities in elementary educational settings resulted in respiratory illness reduction up to 50.6% (Guinan et al., 2002). These authors also noted that teaching children appropriate hand hygiene techniques leads to the reduction of infectious diseases and the decrease of missed school days due to infectious disease. For instance, a study conducted on mandatory hand washing revealed reduced gastrointestinal and respiratory disease (influenza A) incidents among elementary school children by 52% and missed school days by 26% (Stebbins et al., 2011). The study on implementation of a hand washing course at a Navy training center revealed that the outpatient visits for respiratory illness decreased 45% and the prevalence and incidence rates of respiratory illness were much lower among frequent hand washers (Anderson et al., 2008). The use of alcohol gel hand sanitizer is another effective intervention procedure. For instance, the use of sanitizers (70% ethanol) in an elementary school reduced missed school days due to illness by 19.8% among 6,000 students in 16 elementary schools (Guinan et al., 2002). The implementation of sanitizers in a university setting resulted in 40% reduction in absenteeism and lower rates of respiratory illness from 14% to 39.9% (Black et al., 2013).

Furthermore, hand washing with soap is recommended as an effective method in reducing the risk of food anaphylaxis (severe allergic reactions) among school children by the CDC (2014). According to CDC (2015) guidelines, all children in classrooms with various food allergies have to follow recommended control and preventative measures to prevent the risk of life-threatening allergic reactions among students with certain food intolerance. Such control and preventative procedures include mandatory hand washing and routine disinfection of frequently touched school objects and surfaces to reduce the risk of allergic reactions.

2.9.1 Hands are the Primary Mode of Pathogens Transmission in the Population

According to Jumma (2005), hands contaminated with microorganisms are the prime mode of communicable diseases propagation among the human population. Human skin has two main types of microorganism populations, which includes resident flora and transient (contaminant) flora (Pittet & Boyce, 2001). According to Jumma (2005), the resident flora is located on the deeper skin layers (the sebaceous glands), and microorganisms on these layers are unassociated with hand hygiene practices. Further, she postulated that the inhabitant flora comprises mostly Micrococcus spp, Corynebacterium spp, coagulase-negative staphylococci, and Propionibacterium spp. These microorganisms contain low pathogens and are less likely to cause an infection unless the skin is damaged.

Pittet and Boyce (2001) asserted that the transient flora is less adhesive because of the superficial skin layers. Furthermore, they noted that the transient flora consists of infectious agents associated with nosocomial infections (Escherichia coli and Pseudomonas aeruginosa) and viruses. The transient flora is characterized by a short survival rate and high pathogenic ability (Jumma, 2005). As a result, it easily spreads via immediate hand touching between human skin and fomites, but can be easily removed via hand hygiene (Pittet & Boyce, 2001).

2.9.2 Hand Hygiene

Hand hygiene refers to a method of removing microorganisms from the hands (CDC, 2014). Maintaining proper hand hygiene, which is a primary preventative measures, is considered to be a critical method according to the CDC in preventing and controlling the propagation of infections in populations. Primary prevention refers to the prevention of “the development of the disease by reducing exposure to disease causing agents or by immunization, denotes intervention before the disease has developed” (Gordis, 2009, p. 313). These activities are effective before pathological onset and reduce significantly the incidence of disease (Aschengrau & Seage, 2008).

The negative impact of hand hygiene on pathogen spread has been known for many centuries and dates back to the hand washing practiced as a cultural and religious belief, rather than to the infection prevention practices (Jumma, 2005).

For instance, the lower mortality rate among Jews during the Plague pandemic in the 14th century was associated with the ceremony of hand washing, which was practiced in Jewish religion via ablution promotion (Jumaa, 2005; Ligon, 2001). Another persuasive example of the efficacy of hand hygiene on the decreasing incidence and mortality rates was confirmed by Ignaz Semmelweis. After Semmelweis developed and instituted a policy on mandatory hand hygiene in Vienna General Hospital in 1847, the mortality rate among mothers due to puerperal fever reduced six times (Black et al., 2013).

Hand washing with soap is considered to be one of mostly common types of hand hygiene used to reduce communicable diseases spread in the population. According to CDC (2014), the process of hand washing is "defined as the vigorous, brief rubbing together of all surfaces of lathered hands, followed by rinsing under a stream of water" (para. 3). Jumma (2005) stated that proper hand washing techniques involve several critical steps: the use of running water and soap, rubbing hands dynamically for at least 20 seconds, and drying hands with a paper towel. Further, she emphasized that washing hands with soap enables suspension of pathogens and elimination by mechanical rinsing. The time spent on hand washing is critical to decrease pathogens transfer to other people, environmental surfaces, and food. According to CDC (2014), the nail area and area between the fingers is known to harbor many pathogens; therefore, these areas should be washed more thoroughly during the hand washing process. Jumaa (2005) asserted that hand drying also is an important aspect to eliminate microorganism spread, as wet hands transmit more microorganisms than dry hands. Additionally, drying hands repetitively with reusable cloth towels should not be practiced to avoid cross-contamination (CDC, 2014).

2.9.3 When Is Hand Washing Required?

Black et al. (2013) asserted that every time hands are considerably soiled with pathogens and cross-contamination spread may occur, hand washing is essential: before, during, and after cooking food; before and after eating and drinking; after using a bathroom; after cleaning up a child who used the toilet/urinal and after changing diapers; after sneezing, coughing, and blowing one's nose; before and after caring for someone who is ill; after handling pet food and waste; and after handling garbage.

2.9.4 Compliance with Hand-Washing Practices

A recent study conducted on hand hygiene compliance in public restrooms found out that only five percent of people properly washed their hands (washing with soap, rubbing, rinsing) for the period of 15 seconds (Borchgrevink et al., 2013). About 33% of the studied sample didnot use soap and 10% skipped washing at all. The average time spent on hand washing was six seconds, which was far below the CDCs recommended 20-second time-frame. Hand-washing compliance is directly linked to such variables as gender, age, cleanliness of sinks, part of the day, and presence of reminding signs (Borchgrevink et al., 2013; Scarborough, 2002; WHO, 2008).

In a study conducted by Borchgrevink et al. (2013), gender was a significant factor with hand-washing compliance. For instance, hand washing practices among men were 50.3% in comparison with women at 77.9%. Approximately 35.1% of men and 15.1% of women just wet their hands, and 14.6% of men and seven percent of woman did not wash their hands at all. Older people tend to wash hands more (70.3%) in comparison to college student (64.8%). The presence of a sign promoting hand washing with soap impacted hand washing success rates among participants 68.5% (with signs) versus 60.5% (without signs). In a study conducted on food-handling workers in restaurants only 32% washed their hands. Black and Hill

(2013) reported that only 68% of young adults performed hand washing after using the bathroom and 39% do not wash hands after sneezing, coughing, and blowing their nose. Another study on secondary school children indicated that only 58% of girls and 48% of the boys washed their hands after using the bathroom; however, soap usage for the girls was only 28% and for the boys 8% (Guinan et al., 2002). Problems such as lack of time and adequate proper facilities make it difficult to maintain hand hygiene in a school setting.

2.9.5 CDC Guidelines

Though the positive impact of preventative measures is plausible, exact policies on mandatory hand hygiene practices and cleaning and disinfection of classrooms during the flu season in elementary schools do not exist. However, the routine mandatory hand washing with soap, workplace cleaning, and disinfection are in effect all the year round in classrooms with food allergies. According to CDC (2013), these preventative measures are based on federal laws and regulations.

The only recommendations that are in effect during the flu season are the CDC guidelines for K-12 schools (CDC, 2014). According to these guidelines, it is recommended to promote everyday preventative measures among students, parents, and school personnel to reduce the spread of germs. The CDC's preventative procedures comprise educating students and staff on proper respiratory etiquette (cough and sneeze in the sleeve) and the providing appropriate supplies (tissues and no-touch trashcans). Next, education on proper hand hygiene is critical to reduce the spread of the flu. It includes using soap and water for about 20 seconds, then using a paper towel to dry hands and another one to turn off the faucet. A hand sanitizer containing at least 60% alcohol may be used if water and soap are not available and hands are not visibly dirty. Routine cleaning and disinfecting of frequently touched objects and surfaces, such as faucet handles, doorknobs, desks, hands-on learning items, computer keyboards, and phones is also critical to reducing and eliminating flu and respiratory illnesses. Encouragement of students and staff to implement isolation, such as staying home when sick (fever 100F or higher, cough or sore throat), through education and policy.

Though intensive influenza pandemic planning is in effect at the Department of Health and Human Services (HHS) and at the WHO, precise planning is decelerated by several limitations (Quammen, 2012). The major drawbacks for planning include the gaps in epidemiological data such as means of emerging virus detection, mode of transmission, effectiveness of therapeutic control measures, and lack of ethical, timely and cost-effective procedures for measuring the impact of prevention interventions on the spread of flu and population health (Halder et al., 2010). The best way to control the spread of communicable diseases is to understand how these diseases transmit in the population and to determine the proper control measures to prevent wide proliferation of them. Epidemiological modeling is the most effective, safe, economical, and ethical way to test the efficacy of different control interventions.

2.10 Summary

This chapter provided an overview of relevant literature on the health risk and economic burden of influenza disease. The greatest threat of influenza virus transmission appears to be from school age children. The school age children and school environment are the primary mode of influenza virus transmission. Hand hygiene compliance is essential to prevent and control influenza. In particular, increasing hand washing with soap compliance in educational settings could be an effective method for reducing incidence rates among children and the overall population during influenza season. This chapter also covered the definition of an infection and the ways infections transmit in the population of individuals. The historical perspective on epidemiological modeling, the main types of epidemiological models, and the key phases in building an epidemiological model also were described in this chapter. It was pointed out that computational infection transmission models are novel types of models that encompass various features of the traditional epidemiological models. These types of models are best suited to model complex human behaviors and replicate the contact among individuals as a primary way for infection transmission in certain environments.

It was mentioned that agent-based modeling is a proper approach to mimic human behaviors. The basics in creating an agent-based model include defining the object of simulation and the population of agents and identifying agents' adaptive and interactive (cooperative or competitive) features. Agent-based simulation models allow scientists to implement control measures into the model and measure their efficacy on the disease spread. It also was pointed out that agent-based modeling could be an ethical, cost-effective, and useful analytical method to quantify the effect of hand-washing with soap on influenza incidence rates in the educational setting. No research, however, has been done in this area.

Table 2.2
Agents' Qualities with Definitions

Quality	Definition
Adaption	The ability of agents to modify their activities over time, depending on the system's present state or their previous activities
Autonomy	The capability of agents to function independently of other agents
Awareness	The condition of an agent to recognize the system's state
Heterogeneity	Agent's behaviors and adaptions of a certain state varies among agents
Independence	Each agent maneuvers freely without direct control from devices or humans
Interactivity	Agents are capable of interchanging resources or information with each other
Goal-Oriented	Agent's activities are directed to achieve an objective
Memory	An agent is able to recall its own and the system's current and earlier states
Mobility	Agent is able to relocate within the environment
Pro-activeness	Agents are provided with goal-oriented behaviors and take initiative to fulfill the objective
Rationality	Agents activities are directed towards their advantages
Re-activeness	The ability of agents to change their state or behavior in response to changes in other agents' behaviors or the environment
Social Ability	Communication among the agents occur via interaction language (sending and receiving messages) to fulfill the goal

CHAPTER 3. FRAMEWORK AND METHOD

Influenza, being a highly contagious disease, negatively impacts the quality of life. It represents a serious health risk and economic burden, which puts at risk the country's security and disrupts the core spheres of its stability, such as public health, economy, and education. School children are considered to be the disseminators of influenza virus in the society, due to the fact that they do not observe hand hygiene preventative measures, which contributes to cross-contamination and rapid virus circulation in crowed facilities. The solution to this problem has been identified as improving hand washing compliance amongst school children. Improved compliance of hand hygiene is a keystone of infection control. Several studies have demonstrated the efficacy of this easy, effective, and economical method. However, there are no experimental studies that employed the computational epidemiology method to quantify the impact of improved hand washing compliance on the influenza-related incidence rate and absenteeism in an educational environment.

This study is focused on the analyses of influenza propagation by indicating how the agent-based simulation modeling approach can be employed to measure the effectiveness of control measures and to assist in improving health policy to decrease absenteeism among elementary students. The primary objectives of this project are to examine and measure how the independent variables hand washing with soap, the physical environment, behaviors, and policies related to hand hygiene impact influenza propagation in an educational setting, as outlined in Chapters 1 and 2. This chapter delineates the quantitative method that was employed in this study, including developing an agent-based simulation model, sample set, data sources, and analyses procedures. The discussion of the data validity of this project concludes this chapter.

3.1 Theoretical Paradigm

Boner (2004) advocated that using a theoretical paradigm is essential in research studies. The author postulated that it "provides the assumptions that guide the research, helps the researcher to choose appropriate questions for a given study, and directs the researcher toward data collection methods that are appropriate for the study" (p. 620). This research employed the quantitative method. The epidemiological framework SEIR (susceptible-exposed-infected-recovered) was used for the present study. This model was appropriate to employ since it accurately reflects the natural history of infectious disease course and enables one to measure the efficacy of certain intervention measures.

The present research can be defined as hypotheses testing study. Sekern and Bougie (2009) stated that studies that incorporate hypothesis testing are best suited to justify the essence of particular relationships. Further, the authors stated that "hypothesis testing is undertaken to explain the variance in the dependent variable or predict organizational outcomes" (p.108).

3.2 Study Design

This study was a prevention trial simulation that used the agent-based simulation modeling approach to determine the effect of hand washing with soap on the influenza incidence rate and absenteeism in a school environment. A prevention trial is an experiment that allows the investigator to determine the effectiveness of a prevention procedure (Black, 2013). This study employed a combination of free and experimental simulation. According to Sekeran and Bougie (2009), in experimental simulation the nature and timing is governed by a researcher, and in free simulation the reaction of the participants to modeled activities is determined by the interaction with other participants or by different incentives. Computer simulations are gaining popularity and becoming an alternative to lab and field experimentation; they are currently widely used in epidemiological research. With the rapid development of information technology and advancement in mathematical modeling computer simulations, particularly agent-based simulation, this method is applied as a problem-solving assessment tool in the public health sector to measure the efficacy of control and prevention methods.

The research design included constructing a SEIR agent-based simulation model using AnyLogic simulation software. This research design was employed to measure the effect of changes in behaviors. The environment in a simulation experiment was artificially created, but mimicked the elementary school educational environment. The environment of the experiment was easily controlled, as the experiment run was via simulation software. Participants were exposed to influenza virus contagion over time and were randomly assigned to hand washing treatment. Causal relations were tested via manipulation and control of the hand washing variable in this simulation experiment.

The research design comprised three major phases. In phase 1, general facts, statistics, and data related to influenza, such as incubation period, illness duration, hand-washing success rate among elementary school children, probability of influenza virus transmission, and infectivity, were collected from recent epidemiological research. Additionally, statistics on average elementary school size and school day period in the State of Indiana were collected and presented in Table 3.1. The above-mentioned data were important in constructing an influenza propagation model and measuring the impact of hand-washing intervention in a school environment. Demographic data such as race, gender, and socioeconomic status (SES) were collected from one of the local elementary school websites. The rational behind collecting the demographics is that such variables as gender, race, and SES are considered to impact hand hygiene compliance in populations (Borshegrevnik et al., 2013).

In phase 2, a hand-washing intervention agent-based simulation model was constructed using the highly regarded AnyLogic simulation software. After the hand-washing model was constructed, the incidence-rate measurement was calculated using data from simulation output. Next, the effect of hand-washing intervention on influenza related incidence rates was measured using Pearson's Correlation Coefficient. Phase 3 involved collecting and measuring the absenteeism rate in classrooms where hand washing was required on a daily basis during the school year. This was compared to classrooms where hand washing was not required. The classrooms with hand-washing intervention was defined as a treatment group. The control group differed from the treatment group only in that the children were not required to perform hand washing. After collecting data on absenteeism, days absent per student in each classroom were calculated.The reduction in absenteeism was calculated for both classrooms to measure the efficacy of hand washing on illness-related absents.

To examine significance in illness-related absences in both classrooms, the researcher performed a t-test using a statistical software SAS, version 9.4. The two-sample t-test procedure was appropriate to perform, since the class sizes were different. A comparison of treatment and control groups were computed. For this research the level of statistical significance was defined as $\alpha = 0.05$. The statistical significance denotes the minimum level at which the null hypothesis (Ho) can be rejected (Moore, 2012). The p - value is the probability, calculated presupposing that Ho is true, that the test statistics will hold a value at minimum extreme as that observed in fact. Small p-value indicates strong evidence against Ho. Thus, the lower significance level indicates higher confidence. Therefore, the results are considered statistically significant when the p-value is less than or equals to α. For this research, phase, the null hypothesis is that "there is no difference between treatment and control groups in absenteeism due to influenza." The distributions for average illness related absenteeism in both groups were presented in graphical format.

3.3 Apparatus and Modeling Method

The research was experimental by design and employed the quantitative approach. The goal was to simulate and measure the impact of hand-washing practices on influenza proliferation among school children. Simulation modeling is performed with certain software tools that use graphic and textual simulation languages. Borshev and Fillipov (2004) stated that there are numerous simulation modeling tools. However, practically all of them were developed to support a certain modeling framework, whether SD or DE. AnyLogic was chosen for this simulation experiment due to the fact that it is the most flexible simulation software and enables the researcher to build a model in various ways.

3.3.1 Modeling Tool

AnyLogic is a multimethod simulation modeling tool developed by the AnyLogic Company. AnyLogic is the single tool that supports all three simulation paradigms: SD, DE, and AB. This program is most suitable for modeling agents' behaviors, their interactions, and interaction with the modeled environment (Borshev, 2013; Emrich et al., 2007; Epstein, 2009). Furthermore, this modeling software enables the user to scrutinize the heterogeneity and complexity of economic and social systems at any level due to the modeling language's flexibility. For instance, AnyLogic is equipped with necessary tools, objects' libraries, and graphical interface to model human behaviors, business activities, and human resources (AnyLogic, 2014). The most recent version of AnyLogic software (AnyLogic 7.2) uses Java language and employs the Eclipse-based Modeling Framework (EMF).

There are multiple advantages of AnyLogic software over the other available simulation modeling software. First, AnyLogic is based on the object-oriented concept, which enables the user to build hierarchical, modular, and accumulative systems of large models. Second, UML statecharts are employed to determine agents' behaviors. AnyLogic statecharts comprise history states, compound states

(states within states), and inner and external transitions. Moreover, statecharts in AnyLogic software are able to determine internal states of agents and their reactions to external activities and to define the state transition of a certain agent. Third, action graphs are used to determine algorithms. Fourth, environment entities enable the researcher to define the agent setting and to gather statistics. Furthermore, events in AnyLogic are employed to designate time-specific or sporadic events. All the above-mentioned characteristics enable the researcher to determine most of agents' behaviors. The specific Java code may be created to define unusual or unpredicted agents' behaviors.

Merkuryeva and Bolshakov (2010) stated that the primary advantage of AnyLogic software is an active entity (agent). According to the authors, this active object possesses unique functions and activities within the environment. The agent's behavior is best determined by the statecharts. Further, the authors advocated that the model constructed with AnyLogic has a set of active entities interacting with each other and functioning concurrently. Another benefit of AnyLogic is that ABM can be easily combined with DE and SD models within one model, whether hierarchical, parallel, or detached (Borshev, 2013). For instance, agents' behaviors may be defined by flow diagrams and agents can be used as objects in SD stock and process-centric flowcharts. All these functions are performed through the graphical editor used in AnyLogic. Additionally, graphical elements and wizard enable the researcher to create agents, their populations, links amongst agents, and networks with minimum coding. Furthermore, AnyLogic is flexible and equipped with necessary libraries to design the model in various simulation methods. AnyLogic is a programming and simulation environment based on the Java language that enables a modeler to create and combine hybrid systems (differential equations, discrete events, and agent-based systems; Borshev, 2013).

This present study employed an agent-based simulation (ABS) modeling method. The agent-based simulation method enables researchers to model phenomena from the "bottom-up" level in order to examine and define agents' behaviors and interactions within the environment and their response to adaptions (Auchincloss & Dietz Roux, 2008). This unique characteristic enables researchers to understand how heterogeneity of the agents impacts the evolving behavior of the entire population. Any agent-based model (ABM) comprises such components as sets of agents' relationships, the agents' environment, and the agents' group with certain behaviors (statecharts; Heath et al. 2011).

The research questions of this study are:

1. What is the effect of hand washing on incidence rates and absenteeism due to influenza in an educational environment?

2. Is there a relationship between hand washing and influenza incidence rates among elementary school students?

3.4 Unit and Sampling

The following sections discuss the hypotheses of the study, population, sample(s), variables, and the measure for success.

3.4.1 Hypotheses

This study employed a quantitative method and the results of the study were used to examine two main hypothesis that were derived from the research question:

> H_0: If a routine hand-washing intervention during the influenza season is implemented, then there is no effect on influenza-related incidence rates and influenza-related absenteeism among elementary school children in relation to before implementing the intervention.
>
> H_α: If a routine hand-washing intervention during the influenza season is implemented, then there is a decrease in influenza-incidence rates and influenza-related absenteeism among elementary school children in relation to before implementing the intervention.

3.4.2 Sample Set

A virtual elementary school setting was built in this simulation experiment. It contained a population comprised of artificial agents who represented elementary school children. The total number of participants in the simulation experiment was 2000 students, who were randomly created by the simulation software. The number 2000 corresponds to an average quantity of students in an elementary school in the State of Indiana (National Center for Educational Statistics, 2003). These artificial agents study and work in the artificial school environment during the seven-hour period (Liao et al., 2005). Fifty-nine percent of the agents (students) had prior immunization to influenza for a period of 90 days (CDC, 2013). Students (agents) were infected with a flu virus at random and performed hand washing with soap intervention at random as well.

3.4.3 Variables

Using the model, several independent variables were manipulated to test the effect of the intervention.

The independent variables of this study were:

- Probability of hand washing with soap performance
- Average time spent on hand washing
- Frequency of hand washing per day

The dependent variables of this study were:

- Influenza incidence rates
- Influenza-related absenteeism among elementary school children

All the variables were quantifiable.

3.4.4 Problem Statement and Input Parameters

This study postulated an initial population of 2,000 individuals in the school, who are represented by the agents (National Center for Educational Statistics, 2001). They study and work in the school during the 6-7 hour period (Liao et al., 2005). Fifty-nine percent of the students are immune to the disease for a period of 90 days (CDC, 2013). The rest of the population (41%) have no prior immunity and are subject to the disease. When an infectious individual contacts a susceptible one, the probability of infection is 0.5 (Mikolajczyk et al., 2008). A person stays asymptomatic during the latent period (2 days) and is in an exposed phase (Heymann, 2008). After the incubation period, the person is infectious for 14 days. After a person recovers, s/he is immune for 90 days. However, since the immunity of recovered students lasts only 90 days, students are able to be infected by sick students after the immunity period ends (recurrent stage). Social contacts are the most important channel of disease spread in a population (Skvortsov et al., 2007). The ContactRatePerMinute parameter is calculated with a 25.1/day contact rate for children (Mikolajczyk et al., 2008). According to Mao and Bian (2011), the infectivity for school-aged children was 0.1. The control measure, such as hand washing, is incorporated into the model logic. Thus, susceptible individuals go through the hand-washing stage with a success rate of 36% (Guinan et al., 2002). Students wash their hands 4 times during the 7-hour school day (Miller, 2014). The model's input parameters can be viewed in Table 3.1.

3.5 Data Sources

Data for the present study were obtained from primary and secondary data sources. According to Sekeran and Bougie (2009) primary data refers to "information obtained first-hand by the researcher on the variables of interest for the specific purpose of the study" (p. 180). For instance, primary data sources may include individual interviews, focus groups, and panels. For the present study, the

Table 3.1
Key Parameters for Influenza Propagation Used in the Model

Parameters	Value	Source
Initial Population	2000	NCES, 2001
Incubation Period	2 days	Heymann, 2008
Illness Duration	7-14 days	CDC, 2014
Infectivity	0.1	Mao & Bian, 2011
School Day Period	6-7 hours	Chao et al., 2010
Immunity from Flu	59% for 90 days	CDC, 2014
Probability of Infection	0.5	Mikolajczyk et al., 2008
ContactRatePerDay	25.1	Mikolajczyk et al., 2008
ContactRatePerMinute	0.0174305556	Miller, 2014
HW practices with soap	4 times/day	Miller, 2014
HW practices with soap	1.75/hour	Miller, 2014
HW success rate	36%	Guinan et.al., 2002

semi-structured interview method was chosen. This type of interview was chosen by the researcher due to the fact that semi-structured interviews are best suited for open-ended questions and discussions and they enable informants to freely express their views. Such interviews can provide reliable data.The face-to face interview with the principle of Cumberland elementary school took place on February 27th, 2014 at Cumberland elementary school in West Lafayette. The interview questions are presented in Appendix C of the present research.

Secondary data refers to the information received from existing resources. Secondary data for the current study were obtained from databases, periodicals, government publications, books, census data, and statistical data and is presented in Chapter 2 of this study. The data on the input parameters from secondary data sources is presented in Table 3.1.

3.6 Agent-Based Hand-Washing Model

AnyLogic software was used to build an agent-based model to represent an influenza transmission dynamic. Transmission of the influenza virus in an educational environment was modeled using the compartmental susceptible–exposed–infected– recovered model (SEIR), which was modified into susceptible–hands washed–exposed–infected–recovered model (SHEIR) using AnyLogic. The input parameters were collected from existing research to build the model. Students, who were represented by agents in the simulation experiment, went through every phase of the disease, acquiring behaviors depending on the disease stage the agents were in. The model was run from October 2014 until May 2015 (CDC, 2014).

The agent-based simulation model (ABM) was created to measure the potential spread of influenza and to quantify the impact of control measure (hand washing with soap) in elementary school settings. This model serves three purposes: (a) to assess the risk of influenza spread in elementary school; (b) to model and test hypothesis about the effect of hand-washing practices on influenza-related incidence rates among schoolchildren in educational settings; and (c) to measure whether hand-washing practices can alter behavior, impact the quality of life or even save lives. The user is offered with a presentation window that displays the presentation of the simulation experiment, shown in Figure 3.1. The susceptible-hand washed-exposed-infected-recovered (SHEIR) model was employed to quantify the dynamics of the flu spread and measure the impact of an intervention method such as hand washing in a school setting. After clicking the button, the main view depicts the agents at risk to the flu virus (Figure 3.2).

Figure 3.1. The Model's Presentation Window

Figure 3.2. The Model's Launching Window

An agent can go through every phase of the disease and different things can happen to him in each of the stages. The model runs in real time. Depending on the input parameters, the agents move through the stages acquiring certain behaviors, changing color in accordance with the changes. According to the natural history of a disease, it is proposed that a student can potentially be in one of the disease course stages and different thing can happen on the four stages of the disease course. This type of behavior is best modeled via statecharts (Borshev, 2013). The four stages of the statechart correspond to 4 phases of the disease course and the fifth statechart denotes primary prevention, which is hand washing with soap.

To illustrate the spread of influenza, certain input parameters have to be determined. For this experiment, those parameters were incubation period, illness duration, infectious rates, school-day period, immunization probability, probability of infection, contact rate, and number of hand-washing practices, and hand-washing success rate among children. Immunization probability refers to the proportion of population that was immunized from the influenza virus. Incubation period is the period of time to reveal influenza symptoms. Illness duration is defined as the period of time an agent is ill until full recovery. Contact rate is the amount of times agents in the simulation environment will have contact with other agents. Infectivity is defined as the probability of becoming infected from an infected agent.

Survival probability is the probability that an infected agent will die from influenza. Hand-washing success rate is the variable that was manipulated to demonstrate the effect of the intervention on the agents' incidence rates. Hand-washing success rate was initially set on 0% to demonstrate the propagation of the influenza virus among completely susceptible agents in a virtual elementary school environment.

At the beginning of the simulation experiment, a student was susceptible to the infection and remained in this state until s/he succumbed to the influenza virus. The influenza virus could be transmitted during contact and was modeled by the message from one agent to another. The susceptible pool was represented by the agents at risk for the infection who did not obtain a prior flu immunization. A susceptible agent is an individual who has not yet been infected and is at risk of infection. The transition from the susceptible to exposed pools was triggered by the message "Infection." Once the student got the message s/he moved to the exposed state, where the agent was infectious with no symptoms. The exposed group consisted of asymptomatic agents who had contracted the virus and were in the subclinical phase.

The agents were infected at random. Agents who were infected with the influenza virus at first had to undergo an incubation period when they were not infectious and did not have influenza symptoms. The incubation period for school-age children was set at 2 days. After the incubation period, an agent revealed the influenza symptoms. Timeout for the next transition was triggered by the message "IncubationPeriod*uniform(2)," and the agent moved to the Infected state. The Infected group included agents who developed and exhibited influenza symptoms and were contagious. Two possible outcomes from the Infected state were available for students: an agent survived with a survival probability of 95%, this action being triggered by the timeout "Illnesss Duration*uniform(0.5, 2);" or the agent moved to the deceased pool and was removed from the model.

The recovered group contained agents who had received prior immunization or had recovered from the disease and thus acquired immunity and were added to herd immunity. This was reflected in the Recovered pool, where agents did not react to the message “Infection.” However, after the immunity was over, agents were in the recurrent stage and moved to the susceptible pool. This action was triggered by timeout “ 90*().” The Handswashed group was represented by the agents who washed their hands with soap. The agents who did not recover from the disease moved to the deceased group. After running the simulation experiment, simulation results were tabulated. The next simulation experiment ran with a 36% hand-washing success rate to demonstrate the effect of hand-washing intervention on influenza-related incidence rates. The hand-washing variable was manipulated to identify the optimal hand-washing success rate to decrease influenza-related incidence rates during the simulation experiment. The logic for the agents behaviors is depicted in Figure 3.3.

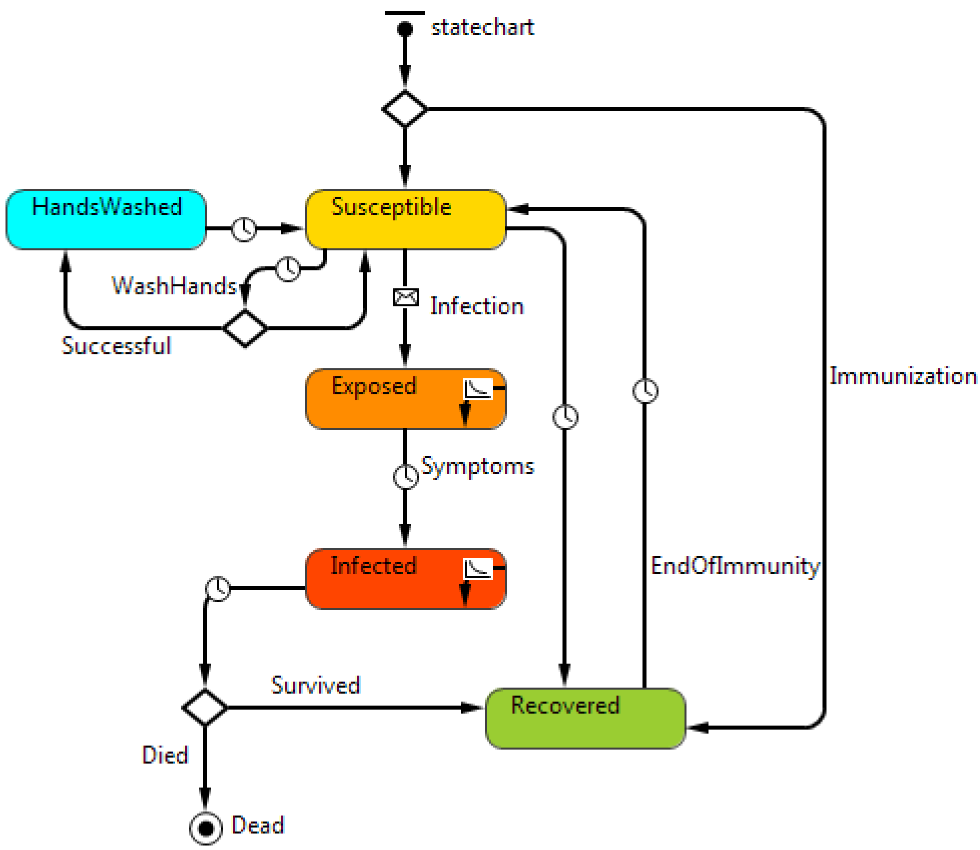

Figure 3.3. Agents’ Behavior Logic

3.7 Reliability and Validity of the Hand-Washing Model

Creswell (2009) advocated that quantitative research requires addressing the reliability and validity of scores established by the study and the assessment tool. Further, the author stated that reliability refers to the extent to which a measuring tool generates constant and stable results. To address the reliability of the model, the author performed a series of simulation experiments and reported the average data from them. Validity is the evidence that the assessment tool used to measure a concept does indeed measure the intended concept. In order to address construct validity (Do items assess hypotheses or theoretical ideas?), the author conducted a randomized comparative experiment in one of the local elementary schools.

The data on absenteeism from flu for the period from October 2014 to May 2015 were collected in classrooms, where children were required to perform hand washing on a regular basis, to measure the validity of the model. The data on absenteeism was anonymous and included only the total number of missed school days. Then the collected data were compared with the data on flu-related absenteeism among children who were not required to perform hand washing daily in the same age category in one of the local schools. Employing this method enabled the researcher to calculate influenza-related absences in two groups and to measure the efficacy of hand washing with soap intervention to test the validity of the simulation experiment.

3.8 Data Analyses

In order to test the hypotheses, it was essential to perform data analyses based on the simulation outcomes. Multiple simulations have to be performed with AnyLogic software to acquire accurate data from the simulation results. It is a highly regarded software, and was chosen as an analytical tool due to the several advantages over other software. For instance, it enables the researcher to collect statistics on agents, calculate numeric properties, create visual graphics based on input and output data, and create 2D and 3D animations. The statistical results from the simulation model were displayed in graphical format. The incidence rates were calculated based on the hand-washing success rates. Simulation results on using hand-hygiene intervention were compared to the simulation results without intervention to determine the efficacy of the intervention on the incidence rates.

To measure the effect of hand-washing intervention on influenza-related incidence rates, the Pearson Correlation Coefficient was calculated using SAS statistical software, version 9.4. To test the hypotheses of the present study, the level of statistical significance was set at $\alpha = 0.05$. The hypotheses for this test were:

H01: There is no correlation between the hand-washing intervention and influenza incidence rates.

HA1: There is a negative correlation between the hand-washing intervention and influenza incidence rates.

To test the validity of the hand-washing model, the data on excusable absenteeism was collected during the flu season in classrooms with and without required hand-washing practices in one of the local elementary schools. Students in the intervention classroom were required to perform hand washing on a daily basis four times during the school-day period. Students in the control classroom were not required to perform hand washing daily. Since excusable absenteeism reflects academic absences due to illnesses on the basis of confirmed medical diagnosis', illness-related absences were measured to assess the efficacy of the hand-washing intervention in these classrooms during the influenza season.

3.9 Summary

In this chapter the author described the application of agent-based modeling methodology to study the spread of influenza in an educational environment. In Chapter 3 the author presented an influenza transmission agent-based model that incorporated hand-washing intervention to measure its efficacy on influenza-related incidence rates among elementary school children. In this chapter the author described the epidemiological framework, research design, and modeling method that were used in this research. Chapter 3 also encompasses description of the modeling tool that was used to create a hand-washing simulation model. This chapter also covered the hypotheses, variables, sample sets, data sources, and input parameters that were used to construct the model. A short section on data analysis concluded this chapter. The results of the simulation experiment and randomized comparative experiment are covered in Chapter 4.

CHAPTER 4. RESULTS

This dissertation is focused on the analyses of influenza propagation. It indicates how agent-based simulation modeling approach can be employed to measure the effectiveness of control measures and to assist in improving health policy to decrease influenza related absenteeism among elementary students. The main objectives of this research were to examine and measure:

- How the physical environment, behaviors, and policies related to hand hygiene impacted the influenza propagation in an educational setting.
- The effect of a control measure (hand washing with soap) on the influenza dynamic in a school environment.

The research questions that lead the present study were as following:

1. What is the effect of hand washing on the incidence rates and absenteeism due to influenza in an educational environment?

2. Is there a relationship between hand washing and influenza incidence rates among elementary school students?

In Chapter 4, the author presents the results of the simulation experiments and examines how hand washing with soap compliance behavior impacts influenza virus transmission in crowded facilities such as schools. In Chapter 4, the author also addresses the issue of simulation model validity and presents the results of a randomized comparative experiment conducted in one of the local elementary schools. In Chapter 5, the author provides the explanations of the results as well as recommendations and conclusions of this research project.

4.1 Simulation Results

Several simulation experiments on influenza propagation in an elementary school environment were performed using an agent-based model. This ABM, or the hand-washing model, was created using the AnyLogic modeling tool. The construction of the hand-washing model is described in Chapter 3 in detail. This model used parameters that are indicated in Table 3.1. After constructing the model, the author implemented a primary prevention, hand washing with soap intervention, and measured its effectiveness on influenza propagation. Then, a statistics collection function was added into the model. This function was employed by choosing the students' population and selecting a Statistics file. Thus, students' susceptible phase was denoted as NSusceptible() and defined with the code "item.statechart.isSateActive (item. Seceptible)." The same steps were taken to define other phases such as "Exposed," "Infected," and "Recovered."

The dynamic forces of the model are compelling. After launching the simulation model, the population of students was represented by 2000 agents in green color, which denoted that all the students were healthy at the beginning of the experiment. Then, after introducing the influenza virus to the population of elementary school children, the author observed how agents altered their color according to health status and disease stage. The model ran in real time from October 2014 until May 2015. This time period was chosen by the author to mimic the influenza activity period as identified by the CDC. The hand washing success-rate variable was manipulated through the simulation experiment to quantify the efficacy of hand washing with soap intervention on influenza propagation in the virtual elementary school. The handwashed success rate variable was set at first at 0%, then at 36%, and 60%. The simulation results are indicated in Figures 4.1.; 4.2.; 4.3; 4.4.; 4.5.; and 4.6.

After running the series of simulation experiments, the incidence rate measurement was used to evaluate morbidity among agents. The incident rate was calculated as "the ratio of the number of new cases of a disease that appear during

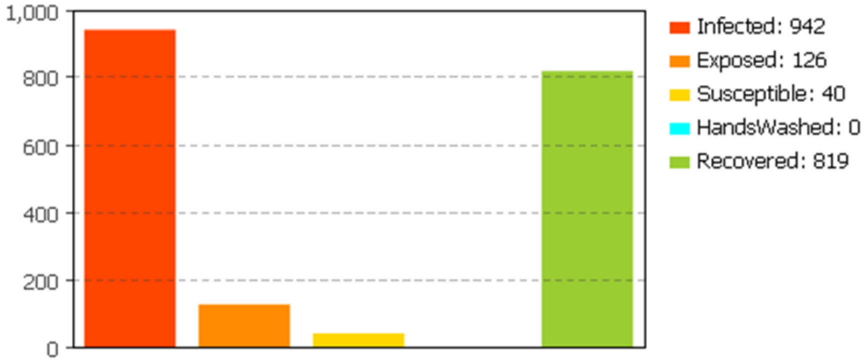

Figure 4.1. Simulation Results with Handwashed Success Rate 0%

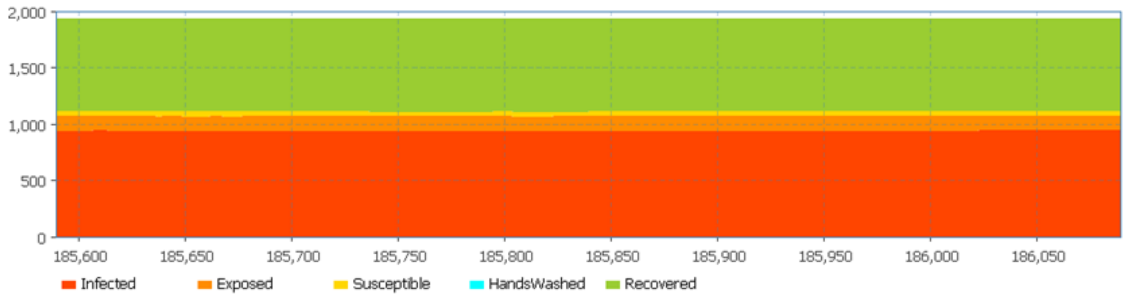

Figure 4.2. Handwashed Success Rate 0%

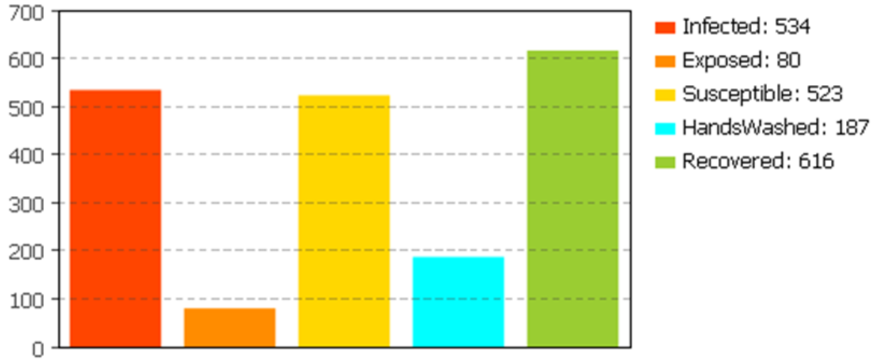

Figure 4.3. Simulation Results with Handwashed Success Rate 36%

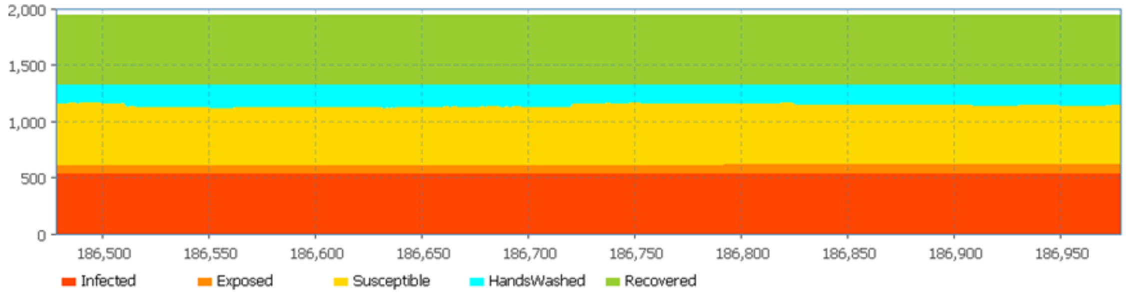

Figure 4.4. Handwashed Success Rate 36%

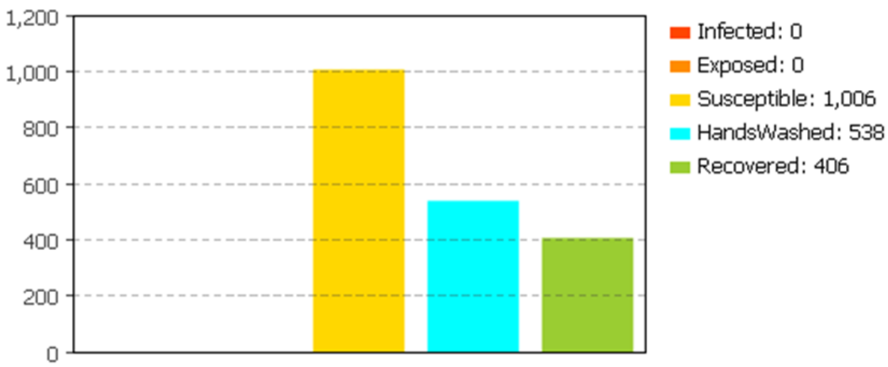

Figure 4.5. Simulation results with Handwashed Success Rate 60%

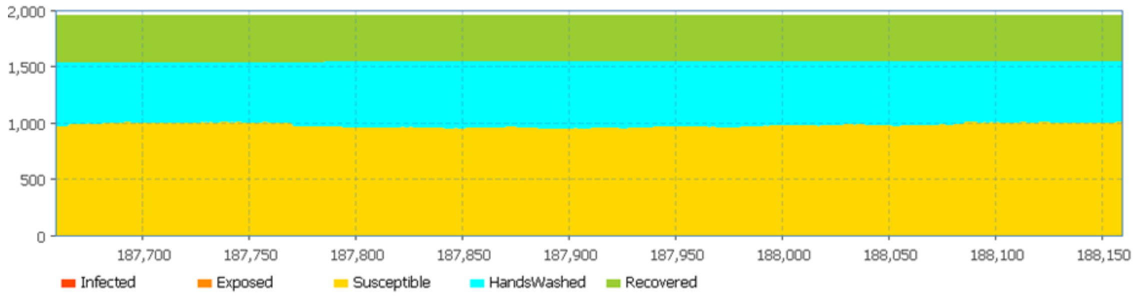

Figure 4.6. Handwashed Success Rate 60%

a certain period of time to the total population at risk for developing the disease, multiplied by K" (Black, 2013, p. 104). Thus, the incident rates for the period from October 1st 2014 to May 23, 2015 among elementary school children in a simulation experiment with a 0% success rate constituted 49% (942/1927 * K) (Figure 4.1 and Figure 4.2). A reduction of incidence rates was observed when the hand-washing success rate was increased to 36% in the simulation experiment, which resulted in a 27% (534/1950) influenza-related incidence rate. The negative correlation between hand washing and the incidence rate was observed and resulted in 22% incidence rate reduction for the same time period (Figure 4.3 and Figure 4.4). The simulation experiment with AnyLogic suggests that hand washing with soap used in an overcrowded environment, such as at an elementary school, promotes the reduction of incidence rates related to the flu.

Further, illness decrease was observed when the handwashing success rate variable was increased from 36% to 60%. Thus, the simulation results for the same time period with 60% handwashed success rate indicated that there were no infected students with the influenza virus. The outcomes of this simulation experiment suggest that incidence rates among students, represented by artificial agents, decrease with the increase of hand washing practices (routine hand washing with soap) during seasonal influenza. Higher percentage of hand washing should result in even lower morbidity. The results of the model (Figure 4.5 and Figure 4.6) indicate that the dynamic of the influenza propagation in an educational setting could be lessened by the incorporation of intervention methods such as simple hand washing.

While running the simulation on the input parameters, it was observed that those agents who performed hand washing with soap four times during the school day period maintained their susceptible status longer than those agents who do not wash their hands. Furthermore, the hand-washing model indicated that routinely-practiced hand hygiene, particularly hand washing with soap, is an effective way to decrease pediatric mortalities associated with diseases transmitted by hands soiled with pathogens, as was advised by the CDC. Running the simulation experiment with 0% handwashed success rate resulted in 73 deaths. Running the simulation with 36% handwashed success rate resulted in 50 agents' deaths. The simulation results suggest that exercising routine hand washing is an effective intervention to reduce morbidity and mortality in an educational setting during the influenza season (Figure 4.6). Additionally, the hand-washing model is able to reflect influenza activity in the educational setting. For instance, running the simulation experiment with input parameters, the model indicates that seasonal influenza has two peaks during the school year, the first peak in December and the second peak in February, which represents a propagated distribution (Black et al., 2013.

4.2 Correlation Between Hand-Washing and Influenza-Related Incidence Rates

Several simulation experiments were performed to examine the relationship between hand washing and influenza related incidence rates. The independent variable (hand washing) was manipulated using 0%, 10%, 20%, 36%, 40%, 50%, and 60% handwashed success rates to examine the response on influenza incidence rates. The response results from the simulations on influenza incidence rates are presented in Table 4.1.

Table 4.1
Influenza Incidence-Rate Responses to Hand-Washing Intervention

Simulations	Handwashed Success Rates	Influenza Incidence Rates
1	0	49
2	10	45
3	20	38
4	36	27
5	40	26
6	50	0
7	60	0

The effect of hand washing intervention on influenza-related incidence rates was measured using the Pearson Correlation Coefficient. Moore et al. (2009) argued that correlation (r) measures the direction and strength of the linear relationship between two quantitative variables. Further, the author noted that the properties of correlation include the following: r is always a numeric value between -1 and 1; $r >$ 0 denotes a positive association; $r <$ 0 denotes a negative association; and values of r close to 0 show a very weak relationship between the variables. The values close to -1 and 1 indicate strong linear relationship between dependent and independent variables. Thus, a correlation coefficient greater or equal to 0.7 indicates a strong correlation between two variables.

The correlations coefficient between hand washing and influenza incidence rates was calculated using SAS statistical software, version 9.4., and presented in Table 4.2 and Appendix B.

Table 4.2
Correlation Between Hand-Washing and Influenza Incidence Rates

		Influenza Incidence Rates
Hand Washing	Pearson Correlation	-0.95683
	P-Value	0.0007
	N	7

The correlation r between hand washing and influenza incidence rates is negative and is represented as r = -0.95683, which indicates a strong negative correlation between these variables. The statistical value of p-value = 0.0007 < α (α = 0.05). The small p-value indicates that the data is statistically significant at level α. Furthermore, the small p-value means that there is enough evidence to reject the null hypnosis (Ho) for this study, that “there is no correlation between hand washing intervention and influenza incidence rates.” Therefore, the data provided sufficient evidence that there is a negative correlation between hand washing and influenza incidence rates. Figure 4.7 represents the scatterplot of the relationship between hand washing and influenza incidence rates.

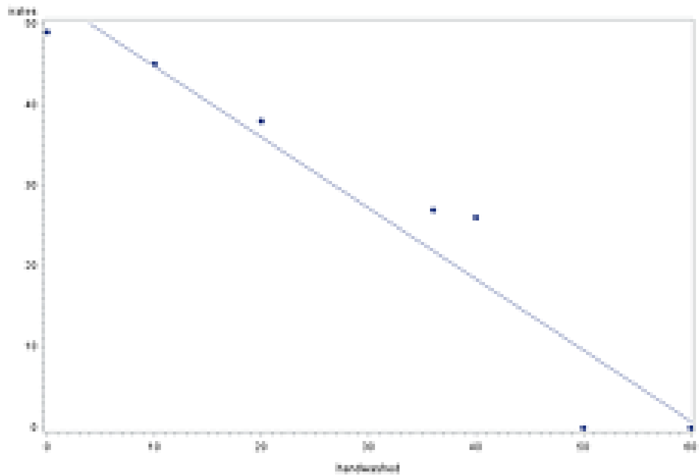

Figure 4.7. Linear Regression of Hand-Washing and Influenza Incidence Rates

The scatterplot indicates a strong linear negative relationship between the hand-washing intervention and influenza incidence rates. The negative relationship between these variables means that higher hand-washing compliance results in lower influenza incidence rates among elementary school children.

4.3 Testing Validity of the Model

The author conducted a randomized comparative experiment to test validity of the model. A randomized comparative experiment is a study where two or more groups are randomly assigned to a treatment to observe the effect of this treatment on the response (Moore, 2012). Since hand washing was required daily in intervention classroom all year round, its plausible to assume that the illness-related absenteeism during the flu season have to be substantially lower in such classrooms than in the control classroom where hand washing with soap was not mandatory. The purpose of this study was to assess the efficiency of hand washing with soap practices on influenza-related absenteeism among elementary school children in classrooms with and without required hand-washing practices in one school in Tippecanoe County.

4.3.1 Demographics

This study was conducted in Cumberland Elementary School, which is a public elementary schools in the city of West Lafayette. West Lafayette is located in north-central Indiana in Tippecanoe County. It is approximately 65 miles northwest of Indianapolis and 103 miles southwest of Chicago. According to a 2010 census, the population of West Lafayette was 29,596 and included more than 54 nationalities. Income per capita in West Lafayette is $22,551 with a median household income of $30,579. The unemployment rate in the city is 3.5% and job growth 1.8%. Purdue University is located in West Lafayette and greatly impacts its economy. Admission to Purdue University in 2010 consisted of 40,000 students, which is larger than West Lafayette's population. About 12,000 people work at Purdue University, the majority of whom reside in Lafayette or West Lafayette. According to the U.S. Census in 2007, about 77% of West Lafayette's population holds bachelor's or higher degrees.

There are three public schools in West Lafayette. These schools belong to West Lafayette Community School Corporation (WLCSC) and include Cumberland Elementary School, Happy Hollow Elementary School, and West Lafayette Junior - Senior High School. Students from kindergarten through third grade attend Cumberland Elementary School. Students attend Happy Hollow Elementary School from fourth to sixth grades. Students from the 7th grade to 12th grade attend West Lafayette Junior-Senior High School. According to Education.com (2015), Cumberland Elementary School has 611 students. The student/teacher ratio is 18:1. The demographic breakdown of the school is as following: approximately 368 (60. 6%) of students are White; 147 (24.1%) are Asian; 31 (5.1%) are Hispanic; 31 (5.1%) are Black; and 34 (5.6%) have two or more races. The students' gender composition is roughly equally distributed and constitutes 51% males and 48% females. Approximately, 11.8% of students are eligible for subsidized lunch. District spending per student is $9,188 per year. In 2010, the district spending for instruction constituted 56%, support services were about 41%, and other services were 3%.

4.3.2 Method

The study is a randomized comparative experiment. At the beginning of the academic year 40 kindergartens were randomly assigned into treatment and control groups. The study involved one individual school in Tippecanoe County. The treatment group included 18 students. These students were required to perform hand washing with soap on a daily basis four times (entering the classroom, after recess, before/after lunch, after using the restroom) during a seven-hour school period. The control-group classroom included 22 students, who were not required to practice hand washing daily. The control group differed from the treatment group only in that the children were not required to perform hand washing. Absenteeism due to illness was registered by the classroom teachers for the period from October 2014 to May 2015 to assess absences during the influenza season in both groups and then the data were analyzed by the researcher using SAS, statistical software program, version 9.4.

4.3.3 Subjects

Two public elementary kindergarten classrooms in one of the Indiana State counties were used in this study. In this elementary school, students studied from kindergarten through third grade. The mean age of students in the studied groups were 6 years old, and the boy girl ratio composition in the studied groups was 1:1. These kindergartners were from middle class families. Students in studied groups attend school for the “full (seven hour) day period.

4.3.4 Protocol

Students in the intervention group were met in the hallway in front of their classrooms by teachers and were instructed to perform hand washing with soap in the restrooms first thing in the morning before entering the classroom, then during the day (before/after lunch, after using the restroom). The teacher in the treatment group was responsible for encouraging the mandatory hand washing with soap according to food allergy prevention recommendations. The researcher did not have any direct observation of students washing their hands and did not record any personal information about the students.

This study defined illness-related absenteeism as an amassed number of days missed from school due to communicable diseases in the period from October 2014 to May 2015 in the treatment and the control classrooms. The total illness-related absences were recorded by classroom teachers in both groups. The data from teachers on absenteeism due to illnesses was received with no identification of individuals in the study. Respiratory illnesses-related absences were recorded and kept by the teachers during the studied period. The respiratory illness-related absences were identified on the basis of confirmed doctors' diagnosis communicated to the school personnel or notified by students' parents. Other types of excusable and inexcusable absenteeism, such as injuries, doctors visits, and absences due to family issues were not recorded. The data on illness-related absenteeism from the classrooms were provided without any students being identified.

4.3.5 Data Analysis

This study involved 40 students from separate classrooms within the same school district. The intervention group practiced hand washing with soap during the entire period of the study four times a day, while the control group was not required to perform hand washing regularly after certain activates on the daily basis. In the control classroom with 22 students, a total of 151.5 absences due to illness was reported. In the intervention group, which had 18 students, a total of 82 illness-related absences were reported. Days absent per student for the period from October 2014 to May 2015 was determined as a ratio: the total illness-related absences divided over the number of students in this classroom. The “peanut free Room = 82/18= 4.56. The classroom without peanut allergies=151.5/22= 6.89.

The proportion reduction in illness-related absents for treatment classroom who were required to perform hand washing with soap four times during the school day was calculated as a proportion: The Reduction in Absenteeism = total illness-related absences in the control group - total illness related-absences in the treatment group / total illness-related absences in the control group *100 = 151.5-82/151.5 *100= 45.9%. After the results of absenteeism due to illness in both groups were assessed, the overall decrease of absenteeism due to respiratory illnesses was 45.9% in the treatment group, which routinely practiced hand washing with soap, in comparison to the control group. The average illness-related absences per students in the treatment and the control groups for the period of eight months (from October 1, 2014 to May 21, 2015) were plotted and presented in Figure 4.8.

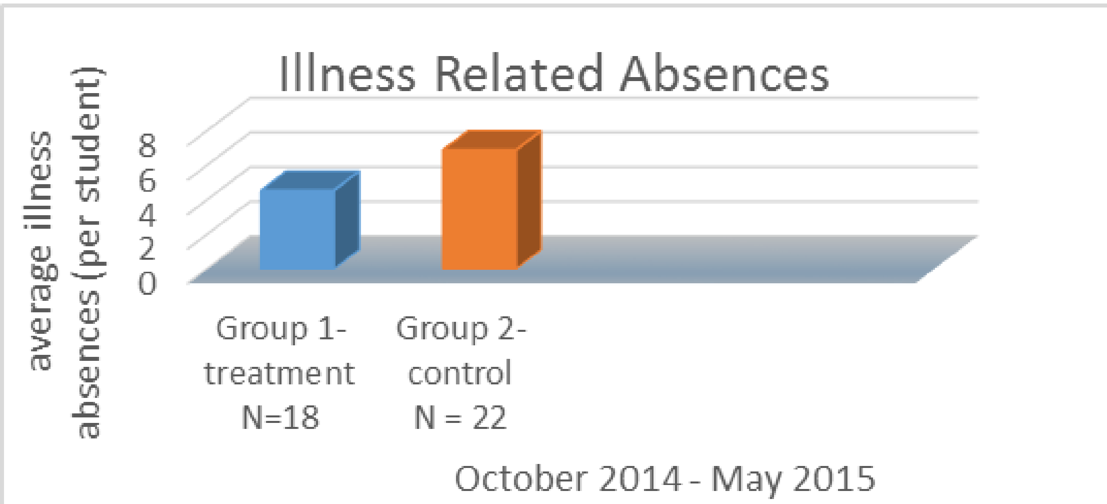

Figure 4.8. Average Illness-Related Absence

More (2014) argued that when the sample sizes, are different in size the t-test is the most appropriate statistical procedure to employ to compare the mean response in the two groups. Further, the author stated that the small sample sizes demand special attention, since the power of significance tests may be low, and the confidence intervals of margin of errors may be large. The author also asserted that in spite of these complexities, the important conclusions from the studies with small and unequal sample sizes can be drawn using two-sample t-tests.

4.3.6 Difference in Illness Related Absenteeism

A two-sample t-procedure was performed for unequal sample sizes using the SAS program to compare two means of studied samples and to identify if the illness-related absence in the treatment was less than in the control group and statistically significant with $\alpha = 0.05$. The SAS output is presented in Appendix A. Side-by-side boxplots presented in Figure 4.9. indicate distribution of absence by the treatment and control groups. The distributions for average illness-related absenteeism in both groups are roughly symmetrical and unimodal (Figure 4.10). The QQ plots look roughly normal, without obvious outliers (Figure 4.11.).

The treatment group is slightly skewed to the right, however severe departures from Normality, which would have prevented the researcher from using the t-procedure are not observed. Therefore, to test the hypotheses, the researcher performed a significance test. The results are presented in Appendix A and the statistics are summarized in Table 4.1.

Since sample sizes were small and unequal, the F-test was performed to test equality of variance. A chi-square test was employed to examine if the variance of a population is equal to a specified value. Two hypotheses were tested with a significance level of $\alpha = 0.05$. The null hypothesis is Ho: $\sigma\ 1^2 = \sigma\ 2^2$, meaning that the variances are equal, and Ha: $\sigma\ 1^2 \neq \sigma\ 2^2$, meaning that variances are not equal. The results of the F-test indicate that $p = 0.\ 2300$, meaning that $p = 0.\ 2300 >$

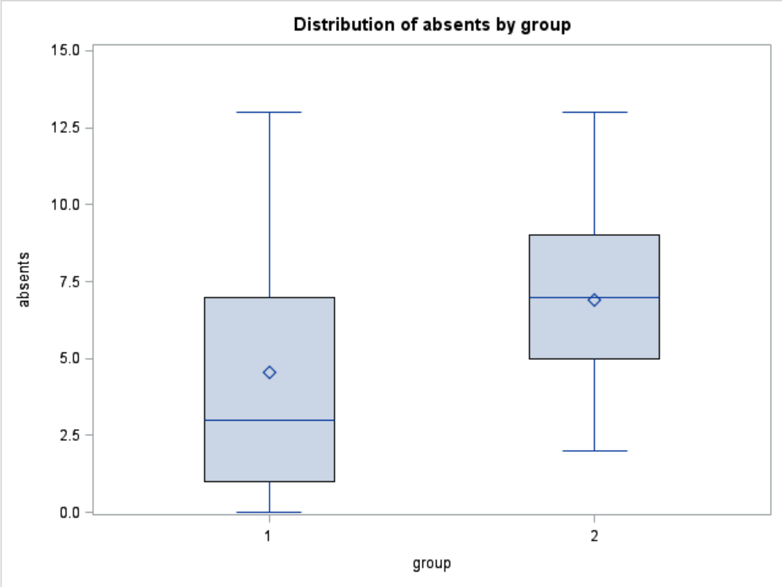

Figure 4.9. Distribution of Absences by Group

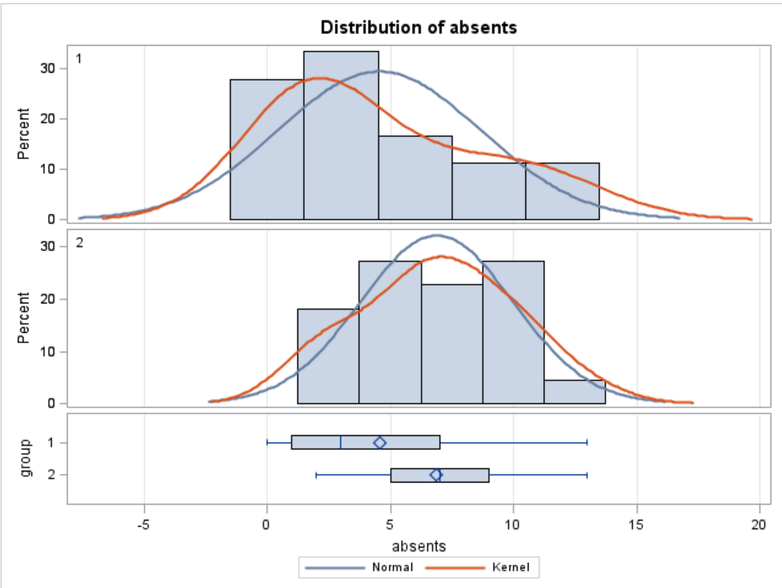

Figure 4.10. Distribution of Absences

0.05. The data provides evidence that failed to reject Ho and so it is concluded that the variances are equal. Since equal variance is satisfied, the researcher used pooled equal variances value (Appendix A).

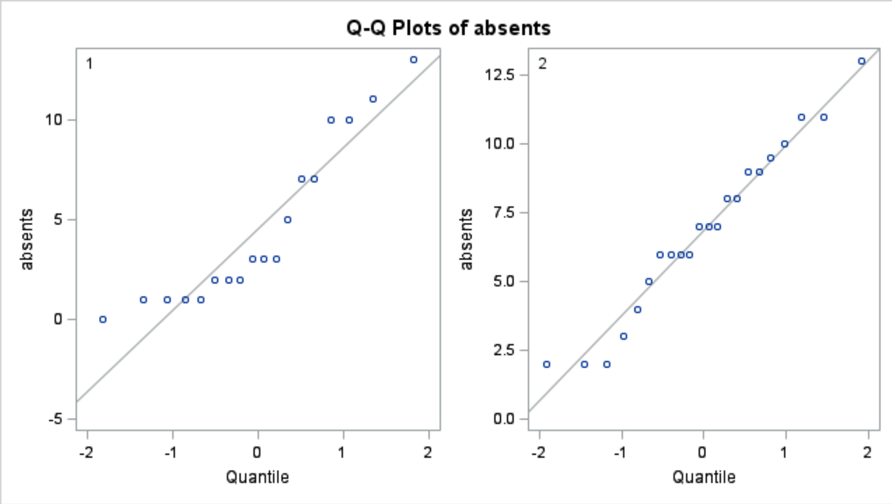

Figure 4.11. Q-Q Plots of Absences

Table 4.3

Data from SAS Output on Illness-Related Absences

Total number of students	Total number of absences	Absentee rate	Mean	SD	t	DF
N=18 group 1 - treatment	82	45.6%	4.5556	4.0761	-2.06	38
N=22 group 2 - control	151.5	68.9%	6.8864	3.0935		

The results of the t-test indicate that the illness-related absenteeism is lower in the treatment group (t= 2.06, df = 38, p = 0.0467). The mean illness-related absenteeism for the treatment group students was 2.33 lower than in the control group. The t-test on illness-related absenteeism indicates significant difference between the treatment and the control groups (with p-value of 0.0467 and α = 0.05). The data provided evidence that the illness-related absenteeism was less in the treatment group than in the control group.

There were two hypotheses tested. The null hypothesis was Ho: $\mu 1 = \mu 2$ - there is no difference between treatment and control groups in absenteeism due to respiratory illnesses. The alternative hypothesis was that Ha: $\mu 1 < \mu 2$ - the illness-related absenteeism is less in the treatment group than in the control group. The assessed results were statistically significant with $\alpha \leq 0.\ 05$ and $p = 0.0467$. A negative t-statistics means that $\mu 1 < \mu 2$. The data provided evidence that the illness-related absenteeism was less in the treatment group, than in the control group.

The preliminary findings of this study indicate a statistically significant decrease in illness-related absenteeism among the students who were required to perform hand hygiene frequently during the school day. The efficacy of hand hygiene on illness-related absenteeism was demonstrated in various studies (Guinan et al., 2002; Hammond et al., 2000). This study demonstrated that respiratory illness-related absenteeism among elementary school children can be significantly decreased by incorporation of routine hand-washing practices in elementary schools.

Moreover, the results of this study are consistent with hand-washing simulation model results on the efficacy of hand hygiene on influenza propagation in an educational environment. Improving hand-hygiene compliance among elementary school children might lower the propagation of infectious diseases in educational environments and reduce illness-related absenteeism among students, teachers, and communities, and might feasibly prevent secondary infections in the community.

4.4 Summary

In this chapter, the author presented the results and analyses of the simulation experiment performed with an agent-based hand-washing simulation model. In Chapter 5, the author provides the explanation of the results, draws inferences in regards to the posed research questions, and provides theoretical and practical consequences of the results.

CHAPTER 5. RECOMMENDATIONS AND CONCLUSIONS

This dissertation demonstrated how and agent-based simulation modeling approach can be employed to measure the effectiveness of control measures and to assist in improving health policy to decrease absenteeism among elementary students. This study examined and measured:

- how physical environments, behaviors, and policies related to hand hygiene impact influenza propagation in an educational setting.
- the effect of a control measure (hand washing with soap) on the influenza dynamic in a school environment.

The first three chapters were devoted to the purpose of the present study, the review of the relevant literature, and method. Chapter 4 provided the presentation of the data and data analyses. Chapter 5 focused on the conclusions that were drawn from the obtained data and provided answers to the posed research questions.

5.1 Findings of the Study

5.1.1 Research Question 1

What is the effect of hand washing on incidence rates and absenteeism due to influenza in an educational environment?

The results of the present study indicate that hand washing with soap, practiced routinely, decreases morbidity among students during seasonal influenza period. The results of the simulation experiment indicated that influenza-related incident rates among elementary school children who did not wash their hands (0%

handwashed success rate) was high and constituted 49% for the studied period. A reduction of incidence rates was observed in the simulation experiment when the hand-washing success rate was increased to 36% and resulted in 27%. Higher percentage of hand washing (60%) resulted in even lower morbidity (0%) for the same period. The simulation experiment with AnyLogic suggested that hand washing with soap introduced on a daily basis in an overcrowded environment, such as elementary schools, is an effective measure for reducing influenza-related incidence rates among students. Furthermore, the results of the model indicated that the dynamic of the influenza propagation in an educational setting could be lessened by the incorporation of intervention methods such as simple hand washing.

The analogous observation was noticed in the study conducted on the effect of hand washing on influenza-related absenteeism. Since excusable absenteeism reflects academic absences due to illnesses on the basis of confirmed medical diagnosis, illness-related absences were collected and measured in the classrooms with required hand washing and no required hand-washing practices during the influenza season. The statistical results of the study confirmed the results of simulation experiment, that hand washing with soap is an effective measure to reduce influenza-related absenteeism among elementary school children. The results of the study indicated the overall decrease in 45.9% of influenza-related absenteeism in the treatment group in comparison to the control group. The statistical results on illness-related absenteeism indicated significant statistical difference between the treatment and the control groups (with p-value of 0.0467 and $\alpha = 0.05$). The mean illness-related absenteeism for the treatment group of students was 2.33 lower than in the control group. The results of the study showed that the illness-related absenteeism was much lower in the treatment group ($t = 2.06$, $df = 38$, $p = 0.0467$) than in a control. This study also demonstrated that hand washing, practiced routinely, is an efficacious measure to reduce respiratory illness-related absenteeism among elementary school children.

The preliminary findings of this study indicate a statistically significant decrease in illness-related absenteeism among the students who were required to perform hand hygiene frequently during the school day. The efficacy of hand hygiene on illness-related absenteeism was demonstrated in various studies (Guinan et al., 2002; Hammond et al., 2000). This study demonstrated that respiratory illness-related absenteeism among elementary school children can be significantly decreased by incorporating routine hand-washing practices in elementary schools.

5.1.2 Research Question 2

Is there a relationship between hand washing and influenza-related incidence rates among elementary school students?

Yes, there is a negative relationship between hand washing and influenza incidence rates among elementary school children. The second research question of the present study was answered by performing a series of simulation experiments using the hand-washing simulation model. The independent variable (hand washing) was manipulated several times to examine and assess the response in the dependent variable (influenza incidence rates). The correlation r between hand washing and influenza incidence rates was negative and p= -0.95683, with p-value of $0.0007 < \alpha$ ($\alpha = 0.05$). The data from the SAS output provided enough evidence that there was a negative correlation between hand washing and influenza incidence rates. The negative correlation indicated that the higher the hand-washing compliance among elementary school children, the lower the influenza incidence rates among elementary school children will be.

5.2 Discussions

Many scholars have shown that hand hygiene happens at the intersection of individual habits and culture. Evidence from previous research indicated that hand washing with soap is rarely practiced in society at large. This suggests that it will be a real challenge to make hand washing with soap a routine habit. The major reasons for low hand hygiene-compliance include lack of proper and consistence education about hand hygiene, skepticism about the value and efficacy of hand hygiene, and lack of rewards for hand-hygiene compliance (Boyce et al., 2002). The possible solution for higher hand-hygiene compliance in society include raising awareness about hand-hygiene importance, educating the public about proper hand-washing procedure (washing all hands surfaces and time required), and providing positive reinforcement.

To be effective, proper hand washing must be learned and shaped during the younger years to become a lifelong habit. Improving hand-hygiene compliance among elementary school children might significantly decrease the propagation of infectious diseases in educational environments and reduce illness-related absenteeism among students and teachers. It also might feasibly prevent secondary infections in the community. Hand hygiene is an easy, effective, and inexpensive intervention method for reducing the risk of infectious airborne diseases such as influenza. Moreover, simple hand washing is an effective method of controlling and mitigating the circulation of communicable diseases in an overcrowded environment. Hand washing, performed for just 20 seconds, is considered a "rough-and-ready vaccine to considerably decrease respiratory illness and save lives. Furthermore, hand washing is one of the most innocuous methods to control and prevent risk from communicable diseases in society, decrease absenteeism in schools, and increase productivity.

This technique could be classified under the epidemiological concept of Occam's razor, or minimum intervention (Black, 2014). According to this concept, the simplest intervention that works is the best to explain causality and solve a complex phenomenon (Black, 2014). Black (2014) advocated that hand-washing technique being a simple, effective, and low-cost intervention is defined as a minimal intervention (MI) and could be categorized under the epidemiological concept of Occam's razor. According to Hovell and Black (1989), MI, are defined as "therapeutic or preventive services that (1) result in either small effects in a large proportion of the population or large effects in a small proportion of the population, (2) do not require much money, personnel, technology, or time to provide, and (3) involve little or no risk of side effects" (p. 566).

Further the authors postulated that interventions that satisfy any criterion of these principles would be regarded as the most beneficial, due to their ability to provide a result within limited expenditure. The positive effect of MI was demonstrated in various studies on health-related problematical issues and healthy behavior compliance. For instance, the efficacy of MI programs has been shown to be effective in the areas of physical fitness, weight control, hypertension control, addiction cessation and others (Hovell & Black, 1989; Abood et al., 2002). These results suggest that minimal interventions might be efficacious and applicable to all diseases. Thus, MI is an ideal population-based approach to modifying hand-hygiene compliance behaviors because compliance is positively influenced and results in the likelihood that simple versus complex behaviors will be performed. If only 5% of the population used the intervention, which is a very large number of people in actual numbers, there would be an immense reduction in morbidity, mortality, and injury, and better compliance and greater likelihood of hand-washing behavior (Black & Cameron, 1997). Several studies suggested that implementing hand washing interventions in elementary schools resulted in substantial decrease of respiratory and gastrointestinal illness rates and illness-related absenteeism (Aiello et al., 2008; Curtis et al., 2011; Guinan et al., 2002; Hammond et al., 2000; Rabie & Curtis, 2005; Stebbins et al., 2011).

Recent CDC data (2014) suggested that about 60 million students and seven million school personnel study and work in 130,000 schools in the U.S. By transforming hand washing with soap into a daily habit in schools, educational institutions could to protect 20% of the U.S. population against influenza and other diseases transmitted by dirty hands. Hand washing with soap, being an easy, effective, and economical measure, could save more lives than any other pharmaceutical intervention and significantly decrease morbidity, mortality, and disability from infectious diseases, reducing economic burden and improving the quality of life.

5.3 Recommendations

For this simple preventative measure to be successful, it should be promoted as an integrated strategy by public health, education, emergency management, and policy makers. The public needs to be educated on what constitutes proper hand hygiene and why it is critical. However, research indicates that a top-down approach is ineffective for altering health behaviors. WHO (2008) stated that for the hand washing with soap promotion to be effective, it also should include such agencies as NGOs, religious organizations, the private sector, various types of media, and community groups. Designing a tailored message based on the attitudes, motivations, interests, and needs within a targeted community might be the most effective way to change hand hygiene-related behaviors.

The outcomes of improved hand hygiene among elementary school children may have wide-ranging implications. For the students, improvement in hand hygiene practices can result in decrease in illness-related absenteeism and improved academic performance. Since increased academic attendance translates into improved academic performance, elementary schools could display higher-average students' grades and overall academic improvement on standardized tests. For working parents of elementary school children, improved hand-hygiene compliance of their children can translate into less school and work absenteeism, increased work productivity, less spending on health care services and medications, and reduction of overall infectivity in the society, particularly during the flu season.

Further research with AnyLogic software is needed and should be performed to evaluate the efficacy of other nonpharmaceutical methods on the spread of the flu in schools. Computer simulation models designed to simulate the transmission of infectious diseases with a pandemic potential might be an effective tool to test and quantify the efficacy of certain intervention strategies on the diseases proliferation in a timely, safe and ethical manner. Moreover, this novel information technology tool enables researchers to inform key stake holders on how to build and maintain health resilience to infectious diseases in the population before and during of crisis of large magnitude. Additionally, computer simulation models may be an effective method to design and implement preventative health programs in elementary schools and to shape healthy habits and decrease disease transmission in the society at large.

5.3.1 Community, Organizational, and Policy Tactics

The results of the hand-washing agent-based simulation experiment provided valuable knowledge about the effectiveness of hand-washing intervention on the spread of the flu in the educational environment, a type of intervention recommended as a key control-and-response method during the 2009 pandemic influenza. These simulation results have the ability to inform policy makers, public health professionals, educators, and emergency preparedness specialists with evidence-based analyses on the positive impact and significance of routine hand-washing practices on school-children's health. Changing or improving hand washing behaviors is a complex process (OMH, 2008). Therefore, increasing hand-washing compliance must be a multifaceted and integrated approach from public-private partnership and include secondary targets. Such a partnership may include local government, NGOs, the general public, community and women groups, local businesses, religious leaders, academicians from Purdue University, local celebrities, local stores (drug, food, malls), and media (TV; radio; social media) to disseminate a message on hand washing importance.

At the organizational level, the increase in hand-hygiene compliance was observed when mandatory and routine hand-washing interventions and educational programs were incorporated into the daily school curriculum (Guinan et al., 2002;

Hammond, 2000; Stebbins et al., 2011). Additionally, intervention programs that involved whole-community participation have been shown to reduce respiratory and gastrointestinal illnesses (Cutis et al., 2000). Moreover, implementing regulatory hand-washing breaks among elementary school children, like those instituted by DuPage County Health Department, might be an effective policy to reduce illnesses in a school setting.

Furthermore, incorporating polices similar to those exercised in food-allergy classrooms is likely to be effective to decrease the spread of communicable diseases and reduce absenteeism. For instance, according to the law (e.g., RI 2008 Public Law, Chapter 08-086), children in food-allergy rooms are required to wash their hands before entering the classroom, and before and after eating. Additionally, routine disinfection of frequently-used classroom objects is in effect in such classrooms. Next, schools environment also have to encourage hand washing behavior in school children. Based on previous research, hand washing with soap is likely to be practiced when soap and paper towels are available, when posters promoting proper hand washing are present next to sinks, and when sinks are available and clean. Additionally, accessibility of sanitizer pumps is essential when soap and water are not available. For instance, policy intervention programs on hand-hygiene compliance promoted a decrease in school absenteeism by 26% and respiratory-related incidence rates by 52% (Guinan et al., 2002; Hammond et al., 2000).

5.3.2 Hand-Hygiene Promotion and Education

The recent research on hand-hygiene compliance among elementary school children indicates that for hand-hygiene intervention programs to be effective, they should include various methods: in-person observation of compliance by adults or peers; in-person education (online and posters); competitions at the local or school/grade levels; peer pressure to observe a culture of proper and routine hand hygiene; and training in gentle verbal techniques for holding peers responsible and reminding them when they are not compliant (WHO, 2009). Another important aspect is incorporating novel information technology tools and channels into hand hygiene educational process.

5.3.3 Using Information Technology and Social Media

Using novel information-technology tools and channels to educate children and promote knowledge on hand hygiene is essential in our technocratic world. In our rapidly-changing times, information technology is the single effective method that facilitates rapid, engaging, and cost-effective way of gaining and sharing health related knowledge. This is particularly the case with the younger generation to help them form lifelong habits. Thus, information technology tools reach diverse and large audiences across the country and nations. For instance, several effective social media channels are available on hand washing promotion:
https://www.facebook.com/HealthySchoolsHealthyPoepleItsaSNAP;
https://twitter.com /itsasnaporg; and
http://www.schooltube.com/channel/americancleaninginstitute

Furthermore, the YouTube channel is a popular information technology channel to delivering hand washing information to children in an engaging way. For instance, YouTube videos like "Do the Global Handwashing Dance", "Hand Washing for Kids: Pump the Pump", "Handwashing for Kids: Crawford the Cat", "Washy Washy Clean" are engaging and short, reinforcing educational videos on the proper hand hygiene technique.

Another engaging and empowering method is to incorporate video games and apps on hand hygiene into the process of education in elementary schools and into the daily lives of children. For example, video games offered on the following sites offer knowledge on hand washing practices in empowering and entertaining way: https:// www.gojo.com; https://www.carex.co.uk / kids-zone and CLEAN GENE

Hand Hygiene Video and Video Games. A novel app, called "Ella's Hand Washing Adventure" uses a storytteling approach to teach children why, when, and how they should perform hand washing to prevent the spread of infections at home and school. This app is available for free via the ITunes app store and Google play.

5.4 Conclusion

The effect of hand-washing practices was examined on influenza spread in an educational setting by means of a highly regarded simulation modeling tool, AnyLogic. The decreased illness rates among agents who practiced hand washing with soap demonstrates that this simple intervention is indeed an effective method for controlling the propagation of infectious pathogens in a crowded environment. Furthermore, the outcomes of the simulation experiment indicated that regular hand washing practices incorporated in an educational setting is beneficial for reducing influenza-related illnesses among school children, their peers, and close family during the flu season.

The results of this model are consistent with previous quantitative and virological studies on the positive effect of hand washing with soap to reduce the risk of getting sick, eliminate germs, and avoid the spread of germs to others. The effectiveness of this intervention method on the spread of the flu can be enhanced by measuring the efficacy of other preventative measures recommended by the CDC during the flu season, such as routine workplace and fomites' disinfection and using hand sanitizers. The results of this study indicate that incorporation of hand washing with soap practices on a daily basis in an elementary school curriculum provides a simple, effective, and cheap method to decrease morbidity and absenteeism due to respiratory illnesses among elementary school children. Implementing hand-washing breaks after certain activities on a daily basis in the elementary school environment tends to reduce illness and influenza-related absenteeism during flu season. The ultimate health and economic benefits from such intervention might be improved health status of population, reduced school and work absenteeism, improved academic performance, higher work productivity, less health care spending, and improved quality of life in society.

5.5 Summary

In Chapter 5, the author provided the interpretation of the simulation experiment findings, implications, practical recommendations, and conclusions drawn from the presented data.

LIST OF REFERENCES

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Abood, D.A., Coster, D.C., Mullis, A.K., & Black, D.R. (2002). Evaluation of a loss-framed minimal intervention to increase mammography utilization among medically un-and under-insured women. *Cancer Detection and Prevention, 26,* 394-400.

Aiello, A. E., Coulborn, R.M., Parez, V., & Larson. E.L. (2008). Effect of hand hygiene on infectious disease risk in the community setting: a meta-analysis. *American Journal of Public Health, 98,* 1372-1381.

Anderson, J.L., Warren, C.A., Parez E., Lois, R.I., Phillips, S., Wheeler, J., Cole, M., & Misra, R. (2008). Gender and ethnic differences in hand hygiene practices among college students. *American Journal of Infectious Control, 36,* 361-368.

Arino, J., Brauer, F., Van den Driessche, P., Watmouth, J., & Wu, J. (2006). Simple models for containment of a pandemic. *Journal of the Royal Society Interface, 3,* 453 - 457.

Aschengrau, A., & Seage, III. G.R. (2008). Screening in public health practice. In A. Aschengrau & G.R. Seage III (Eds.), *Essentials of epidemiology in public* (pp.411-441). Boston, MA: Jones and Bartlett Publishers.

Auchincloss, A.H. & Dietz Rouz, A.V. (2008). A new tool for Epidemiology: the usefulness of dynamic-agent models in understanding place effects on health. *American Journal of Epidemiology, 186,* 1-8.

Barbati, M., Bruno, G., & Genovese, A. (2012). Applications of agent-based models for optimization problems: A literature review. *Expert Systems with Applications, 39,* 6020-6028.

Black, D.R. (2014). *Lecture 3: Public health terms and public health training.* [PowerPoint slides]. Retrieved from Purdue University Community Health Issues in Homeland Security Blackboard: http://mycourses.purdue.edu.

Black, D. R., Sobiech, N., & Hill, B. (2013). *Foundations of epidemiology* (10th ed.). Oshtemo, MI: Center for Social Problem Solving Measurement.

Black, D.R., & Cameron, R. (1997). Self-administered interventions: a health education strategy for improving population health. *Health Education Research, 12,* 531-545.

Bobner, G.M. (2004). Twenty years of learning: how to do research in chemical education. *Journal of Chemical Education, 81,* 618-625.

Bonabeau, E. (2002). Agent-based modeling: methods and techniques for simulating human systems. *Proceedings of the National Academy of Sciences of the United States of America 99,* 7280-7287.

Borchgrevink, C. P., Cha, J., & Kim, S. (2013). Hand washing practices in a college town environment. *Journal of Environmental Health, 78*(8), 18-24.

Borshev, A. (2013). *The big book of simulation modeling.* AnyLogic North America.

Borshev, A., & Filippov, A. (2004). *From system dynamics and discrete event to practical agent based modeling: reasons, techniques, tools.* Paper presented at 22nd International Conference of the System Dynamics Society, Oxford, England.

Boyce, J. M., & Pittet, D. (2002). Guideline for hand hygiene in health-care settings: Recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. *Morbidity and Mortality Weekly Report, 51*, (RR-16) 1-45.

Bright, K.R., Boone, S.A., & Gerba, C.P. (2010). Occurrence of bacteria and viruses on elementary classroom surfaces and the potential role of classroom hygiene in the spread of infectious disease. *The Journal of School Nursing, 26* (1), 33-41. doi:10.1177/1059840509354383

Center for Disease Control and Prevention (2013): *Everyday preventative actions that can help fight germs, like flu.* Retrieved from http://www.cdc.gov/flu/about/season/. Accessed May 5, 2013.

Center for Disease Control and Prevention (2014): *Business pulse-how CDC protects the health of your business.* Retrieved from http://www.cdc.gov/flu/freeresources/index.htm. Accessed February 2, 2014.

Center for Disease Control and Prevention (2014): *Seasonal Influenza (flu).* Retrieved from http://www.cdc.gov/flu/about/season/. Accessed February 2, 2014.

Center for Disease Control and Prevention (2015): *Food allergies in schools. Voluntary Guidelines for Managing Food Allergies in Schools and Early Care and Educational Programs.* Retrieved from http://www.cdc.gov/healthyschools/foodallergies/pdf/13 2431.

Chao, D.L., Halloran, M.E, & Obenchain, V.J., (2010) FluTe, a publicly available stochastic influenza epidemic simulation model. *Plos Computational Biology, 6,* 1-8.

Creswell, J.W. (2009). Quantitative methods. In J.W. Creswell (3d Ed.), *Research design: Qualitative, quantitative, and mixed methods approaches*(pp. 145-171). Thousand Oaks, CA: SAGE Publications, INC. ISBN: 978-1412965576.

Croteau, M. (2006). *Pandemic influenza in the workplace. 2006.* Retrieved from https://www.aiha.org/localsections/html/crv/PandemicInfluenzanov.pdf. Accessed January, 20, 2014.

Curtis, V. & Cairncross, S. (2003). Effect of washing hands with soap on diarrhea risk in the community: a systematic review. *The Lancet Infectious Diseases, 3,* 275-281.

Dietz, J.E., Chaturvedi, A.R., Black, D.R., Shaffner, J.E., Hseih, C., Dunlop, S., Leonard, K.E., & Burr. J.F. (2012). Developing a prevention and control program with an accompanying simulation. In: Dietz JE and Black DR (Eds.): *Pandemic Planning* (pp. 107-121). NY: CRC Press: Taylor & Francis Group.

Dietz, J. E & Black, R.B. (2012). *Introduction.* Pandemic planning. NY: CRC Press: Taylor & Francis Group.

Emrich, S., Suslov, S., & Judex, F. (2007): Fully agent based modeling of epidemic spread using AnyLogic. 2007. *Eurosim.*

Epstein, J.M., (2009). Modeling to contain pandemics. *Nature* 406(6): 687.

Germann, T.C., Kadau, K.,& Longini, I.M. (2006). Mitigation strategies for pandemic influenza in the U S. *Proceedings of National Academy of Science, 103,* 5935-5940.

Glatman-Freedman, A., Portelli, I., Jacobs, S.K., Mathew, J.I., Slutzman, J.E., Goldfrank, L.R., & Smith, S.W. (2012). Attack rates assessment of the 2009 pandemic H1N1 influenza A in children and their contacts: a systematic review and meta-analysis. *PLOS ONE, 7,* 1-17. Retrieved from: http://www.plosone.org.

Gordis, L. (2009). *Epidemiology* (4th ed.). Philadelphia, PA: Elsevier Saunders.

Greenhouse, S. (2009). Lack of paid sick days may worsen flu pandemic. *The New York Times.* Retrieved from http://www.nytimes.com/2009/11/03/business/03sick.html. Accessed February 15, 2014.

Greenland, K. Cairncross, S. & Curtis, V. (2013). Can we afford to overlook hand hygiene again? *Tropical Medicine and International Health. 18*(3), 246-249. doi:10.1111/tmi.12055

Guinan, M., McGuckin, M., and Ali, Y. (2002). The effect of a comprehensive handwashing program on absenteeism in elementary schools. *American Journal of Infection Control, 30,* 217-220.

Halder, N., Kelso, J.K., & Milne, G.J. (2010). Analysis of the effectiveness of the interventions used during the 2009 A/H1N1 influenza pandemic. *BioMed Central Public Health, 10,* 1-14.

Hammond, B., Ali, Y., Fendler, E., Dolan, M., & Donovan, S. (2000). Effect of hand sanitizer use on elementary school absenteeism. *American Journal of Infectious Control, 2* (5), 340-346. doi:10.1067/mic.2000.107276.

Heath, S.K., Brailsford, S.C., Buss, A., and Macal, C.M. (2011) Cross-paradigm simulation modeling: challenges and success. *Proceedings of 2011 Winter Simulation Conference of Institute of Electrical and Electronics Engineers.* Phoenix, AZ, 2783-2797

Heymann, D.L. (2008). *Control of communicable disease manual.* (19th Ed.). Washington, DC: APHA.

Hovell, M.F., & Black, D.R. (1990). Minimal intervention and arthritis treatment: implications for patient and physician compliance. *Arthritis Care and Research, 2,* 65-70.

Hsieh, Y., Tsai, C., Lin, C., Chen, J., King, C., Chao, D., Cheng, K., & CIDER Research Team. (2014). Asymptomatic ratio for seasonal H1N1 influenza infection among schoolchildren in Taiwan. *BioMed Central Infectious Disease, 14,* 1-10.

Ingelsby, T.V. (2006). Disease mitigation measures in the control of pandemic influenza. *Biosecurity Bioterrorism: Biodefense, Strategy, Practice, Science, 4,* 1-10.

Jumaa, P.A. (2005). Hand hygiene: simple and complex. *International Journal of Infectious Diseases, 9,* 3-14.

Kearney, C.A. (2008). School absenteeism and school refusal behavior in youth: A contemporary review. *Clinical Psychology Review, 28,* 451-471.

Kirby, A., Dietz, J.E., & Wojtalewicz, C. (2012). Modeling of a regional hub reception center to improve the speed of an urban area evacuation. *IEEE Conference on Technologies foe Homeland Security*, 476-482.

Larson, R.C. (2007). Simple models of influenza progression within a heterogeneous population. *Operations Research, 55,* 399-412.

Lewin, E.B. (2012). A paradigm for the control of influenza. *The Journal of Infectious Disease, 202,* 1619-1622.

Liao, C., Chang, C., & Liang, H. (2005). A probabilistic transmission dynamic model to assess indoor airborne infection risk. *Risk Analysis, 25,* 1097-1107.

Longini, Jr. I.M., Halloran, M.E., Nizam, A., & Yang, Y. (2004). Containing pandemic influenza with antiviral agents. *American Journal of Epidemiology, 159,* 623-633.

Luby, S.P., Agboatwalla. M., Feikin, D.R., Billhimer, W., Altaf, & R.M. Hoekstra. (2005). Effect of Handwashing on child health: A randomized controlled trail. *Lancet, 366,* 225-233.

Macal, C.M. (2009). Agent based modeling and artificial life. In Meyers R (Eds). *Encyclopedia of Complexity and System Science* (pp.112-131). Springer: New York.

Macal, C.M. & North, M.J. (2010). Tutorial on agent-based modeling and simulation. *Journal of Simulation, 4,* 151-162.

Mao, L., & Bian, L. (2011). Agent-based simulation for a dual-diffusion process of influenza and human preventative behavior. *International Journal of Geographical Information Science, 25* (9), 1371-1388.

McNeil, Jr., D.G. (2009). In the theory, swine flu started in Asia, not Mexico, *New York Times*, June 23, 2009. Retrieved from http:// www. nytimes.com/2009/06/24/health/24/health/24flu.

Merkuryeva, G. & Bolshakovs, V. (2010). Vehicle schedule with AnyLogic. 12th IEEE International Conference on Computer Modeling and Simulation. doi:10.1109/UKSIM.2010.38. pp. 169-174.

Mikolajczyk, R.T, Akmatov, M.K, & Kretzschmar, M. (2008). Social contacts of school aged children and the transmission of respiratory-spread pathogens. *Epidemiology and Infection, 136,* 813-822.

Moore, D.S., McCabe, G., and Craig, B. (2009). *Introduction to the Practice of Statistics.* Seventh Edition. W.H. Freeman and Company: New York. ISBN -10:1429274336.

National Center for Educational Statistics, (2001). Overview of public elementary and secondary schools and districts: school year 1999-2000. Retrieved from http://nces.ed.gov/pubs2001/overview/table05.asp.

Neuzil, K.M., Hohlbein, C., & Zhu, Y. (2002). Illness among schoolchildren during influenza season: effect on school absenteeism, parental absenteeism from work, and secondary illness in families. *Archives of Pediatrics & Adolescent Medicine, 156,* 986-991.

Nichol, K.L. (2001). Cost-benefit analysis of a strategy to vaccinate healthy working adults against influenza. *Internal Medicine, 161,* 749-759.

Quammen, D. (2012). Out of the wild. Where will the next pandemic come from? And how can we stop it? *Popular Science, 10,* 54-61.

Pittet, D., & Boyce, J.M. (2001). Hand hygiene and patient care: pursuing the Semmelweise legacy. *The Lancet Infectious Diseases, 4,* 9-20.

Plans-Rubio, P. (2012). The vaccination coverage required to establish herd immunity against influenza viruses. *Preventative Medicine, 55,* 72-77.

Rabie, T. and Curtis, V. (2006). Handwashing and risk of respiratory infections: a quantitative systematic review. *Tropical Medicine and International Health, 11,*(3), 258-267.

Ryan, M.A.K. (2001). Handwashing and respiratory illness among young adults in military training. *American Journal of Preventative Medicine, 21,* 79-83.

Sandora, T.J., Shih, M., & Goldmann, D.A. (2008). Reducing absenteeism from gastrointestial and respiratory illness in elementary school students: A randomized, controlled trial of an infection-control intervention. *Pediatrics,121,* (6), e1555-e1562.

Sekaran, U. & Bougie, R. (2010). *Research methods for business: A skill building approach* (5th Ed.). Hoboken, NJ: John Wiley and Sons, Inc. ISBN: 978-0470744796.

Skvortsov, A.T., Connell, R.B., Dawson, P.D., & Gailis, R.M. (2007). Epidemic modeling: Validation of agent-based simulation by using simple mathematical models. *Defense Science and Technology organization*: Retrieved from http://ip-103-1-174-100.ip.secureserver.net/MODSIM07/papers/Skvortsov.pdf

Stebbins, S., Cummins, D.A., Stark, J.H., Stack, J.H., Vukotich, C., Mitruka, K., Tompson, W., Rinaldo, C., Roth, L., Wagner, M., Wisniewski, S.R., Dato, V., Eng, H., & Burke, D.S.(2011). Reduction in the incidence of influenza A but not influenza B associated with the use of hand sanitizer and cough hygiene in schools: a randomized control trial. *Pediatric Infectious Disease Journal, 30,* 1-13.

Szucs, T. (1999). The socio-economic burden of influenza. *Journal of Antimicrobial Chemotherapy, 44,* 11-15.

Taubenberger, J.K. & Morens, D.M. (2006). 1918 influenza: The mother of all pandemics. *Emerging Infectious Diseases, 12,* 13-22.

US Department of Health and Human Services. (2009). Flu.gov: Pandemics and pandemic threats since 1900. Retrieved from http://www.pandemicflu.gov/general/historicaloverview.html Accessed January 14, 2014.

Vessey, J.A., Sherwood, J.J., Warner, D., and Clark, D. (2007). Comparing hand washing to hand sanitizers in reducing elementary school students absenteeism. *Pediatric Nursing, 33* (4), 368-372.

Vynnycky, E. & White R.G. (2010). *An Introduction to Infectious Disease Modeling.* Oxford University Press.

White, J., (2014). Infectious diseases: influenza. *Medical Ecology.* Retrieved from http://www.medicalecology.org/diseases/influenza/influenza. Accessed February 2, 2014

World Health Organization: Disease Outbreak News: Pandemic (H1N1) 2009. Retrieved from http://www.who.int/csr/disease/swineflu/en/. Accessed January 15th, 2014.

APPENDICES

Appendix A: SAS Code and T-Test Output

```
options nodate pageno=1;
goptions colors=(none);
title1 'Illness related absents';
data absents;
input group absents @@;
datalines;
1 7 1 1 1 3 1 3 1 2 1 2 1 1 1 10
1 11 1 7 1 13 1 2 1 1 1 5 1 3 1 10
1 0 1 1
2 10 2 9 2 6 2 13 2 3 2 6 2 6 2 5
2 6 2 2 2 11 2 8 2 11 2 2 2 9 2 7
2 2 2 7 2 9.5 2 7 2 8 2 4
;
run;
proc print;
run;
proc sort data=absents;
by group;
run;
proc boxplot data=absents;
plot absents*group / boxstyle=skeletal;
run;
proc ttest H0=0 alpha=0.05 data=absents;
class group;
var absents;
run;
```

Table A.1

The TTEST Procedure Variable: absences

group	N	Mean	Std Dev	Std Err	Minimum	Maximum
1	18	4.5556	4.0761	0.9607	0	13.0000
2	22	6.8864	3.0935	0.6595	2.0000	13.0000
Diff (1-2)		-2.3308	3.5667	1.1336		

Table A.2

The TTEST Procedure

group	Method	Mean	95% CI	Mean	Std Dev	95 % CI	Std Dev
		4.5556	2.5286	6.5825	4.0761	3.0586	6.1106
		6.8864	5.5148	8.2579	3.0935	2.3800	4.4208
Diff (1-2)	Pooled	-2.3308	-4.6256	-0.0360	3.5667	2.9149	4.5967
Diff (1-2)	Satterthw	-2.3308	-4.7069	0.0453			

Table A.3

The TTEST Procedure

Method	Variances	DF	t Value	Pr > $\|t\|$
Pooled	Equal	38	-2.06	0.0467
Satterthwaite	Unequal	31.191	-2.00	0.0543

Table A.4

Equality of Variances

Method	Num DF	Den DF	F Value	Pr > F
Folded F	17	21	1.74	0.2300

Appendix B: SAS Code for Correlation and SAS Output

```
data a1;
input handwashed irates @@;
cards;
0 49
10 45
20 38
36 27
40 26
50 0
60 0
;
proc print data=a1;run;
proc gplot data=a1;
plot irates*handwashed;run;
proc corr data=a1; run;
for regression line:
symbol1 v=dot i=rl;
title2 'i=rl';
proc gplot data=al;
plot irates*handwashed/frame;
run;
```

Table B.1
Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum
handwashed	7	30.85714	21.72118	216.00000	0	60.00000
irates	7	26.42857	19.94039	185.00000	0	49.00000

Table B.2

Pearson Correlation Coefficients

	handwashed	irates
handwashed	1.00000	-0.95683
p-value		0.0007
irates	-0.95683	1.00000
p-value	0.0007	

Appendix C: Interview Questions

The purpose of this interview was to learn more about hand washing and disinfection practices used during seasonal influenza in Cumberland Elementary School.

1. Name of School:
2. Phone number:
3. How many students are enrolled at your school?
4. What grades are taught at your school?
5. Do you register school absences and how?
6. Are the reasons for absenteeism recorded (illness, family vacation, etc.)?
7. What happens when a child gets sick at your school?
8. Are there any policies in effect on hand washing and disinfection during the flu season at school?
9. What control and preventative measures are in effect in your school during the flu season?
10. How many time do children wash their hands during the school day?
11. Are the classrooms equipped with sinks?
12. Are there scheduled bathroom breaks in classrooms?
13. Are the bathroom breaks supervised?
14. Are there scheduled hand-washing breaks every day in classrooms?
15. Are there any other alternative hand-hygiene practices used in classrooms?
16. Are the classrooms cleaned daily?
17. What methods are used to clean classrooms during the flu season?
18. Is the disinfection of frequently-used objects performed daily?

VITA

VITA

GALINA MILLER

EDUCATION

Doctor of Philosophy Degree 05/2016

Purdue University, West Lafayette, IN.

Dissertation: *Using information technology to improve policies impacting elementary school absenteeism due to influenza*

Master of Science Degree (Education) 12/2011

Purdue University, West Lafayette, IN.

Master of Arts (Linguistics) 07/1997

Bachelor of Arts (English and French Languages)

Minor Psychology

Mari State University, Russia.

RESEARCH EXPERIENCE

Graduate Research Assistant in CNIT 08/2012–08/2014

(Advisor: Dr. Eric Dietz), Purdue University

- Conducted research on communicable disease modeling
- Collected and analyzed data on influenza pandemic prepardness
- Utilized a novel information technology tool to quantify the impact of control and prevention strategies

- Designed a simulation model to evaluate the impact of non-pharmaceutical intervention methods on influenza propogation in the educational environment
- Identified a need for public health promotion and hygiene education among school children to reduce health and economic burdens from communicable diseases
- Analyzed the impact of evidence-based strategies to improve public health and public health policies
- Conducted a research project on integration of Web 2.0 technology to improve risk and heath communication

PUBLICATIONS

Miller, G., Kirby, A., Black, D. R., & Dietz J. E. Evaluating the impact of handwashing practices on influenza propogation in school environnment with agent-based simulation method (in progress).

Miller, G., Dietz, J. E., Black, R. D., Taylor, J. M., & Matson, E. T. The Impact of Hand Hygiene on the Absenteeism among Elementary School Children (in progress).

PRESENTATIONS

Miller, G. Education for Wellness, Cumberland Elementary School, 2010.

Miller, G. Promotion of healthy eating habits and physical activity to reduce the risk of obesity among elementary school children. West Lafayette, IN, 2010.

Miller, G. & Hartford, J. Pandemic prepardness planning. West Lafayette, IN, 2012.

Miller, G. Improving policies impacting school absenteeism among elementary school childen. Purdue University, West Lafayette, 2015.

Miller, G. Clean Hands Bring Health. Program & Evaluation Plan Intervention. Purdue University, West Lafayette, 2015.

Miller, G. Public Health Management of Disasters. TECSUP, West Lafayette, 2015.

Miller, G. Using Simulation Modeling to Improve Policies Impacting Elementary School Absenteeism due to Influenza. `http://wlfi.com/2015/12/04/purdue-simulation-technology-helps-local-schools-control-flu-spread/`

EXPERTISE

Information Technology

- Simulation Modeling
- Topics in Cybersecurity

Technology

- Foundation of Homeland Security
- Technology from Global Perspective
- Emerging Technologies and Technological Change

Public Health Preparedness

- Biostatistics & Epidemiology
- Community Health Issues in Homeland Security
- Designing and Analysis of Health Promotion Interventions
- Health and Risk Communication
- Pandemic Planning
- Emergency Management

Education

- Multicultural Education
- Minority Students Education
- Curriculum and Instruction

Management Skills

- Strategic Management
- Marketing Strategy
- Accounting & Finance
- Leadership
- Negotiations
- Business Law
- Principles of Economics

Software

- SAS
- AnyLogic (simulation modeling)
- Excel, Word
- Photoshop
- Research Databases

TEACHING EXPERIENCE IN ACADEMIA

Purdue University Foundation of Homeland Security	2012
Emerging Technologies and Technological Change	2013
Risk and Health Communication	2013
Community Health Issues in Homeland Security	2014

HONORS

Bilsland Fellowship	2015
Golden Key International Honor Society	2012

Kappa Delta Pi International Honor Society	2011

PROFESSIONAL AFFILIATIONS

American Public Health Association	2015
Institute of Electrical and Electronics Engineers	2016