How Perception of Preventive Behaviors impacts

Seasonal Influenza Outbreaks: An Agent Based Model

Omid Mohammadi

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By: Omid Mohammadi

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Signed by the final Examining Committee:

Dr. Kudret Demirli	Chair
Dr. Daria Terekhov	Examiner
Dr. Fuzhan Nasiri	Examiner
Dr. Ketra Schmitt	Supervisor

Approved by: Dr. Mamoun Medraj

Graduate Program Director

Date________ Amir Asif

Dean of Faculty

Abstract

How Perception of Preventive Behaviors impacts Seasonal Influenza Outbreaks: An Agent Based Model

Omid Moahammadi

Concordia University, 2019

Individual perceptions about preventive behaviours against an infectious disease play an important role in taking appropriate actions to reduce the risk of infection. We developed a Health Belief Model (HBM) by survey instrument in order to understand student perceptions of the influenza virus and two preventive behaviours; hand-washing and vaccination. An educational program was delivered to the treatment group. This health education program was developed by a health promotion specialist and it aimed to increase preventive behaviours and awareness of influenza. The control group answered the questionnaire without receiving an educational program. The two groups were compared and the relationship between preventive behaviours and HBM variables were analysed. An Agent Based Model (ABM) was developed to simulate influenza transmission based on students' health beliefs and how likely they are to apply preventive behaviours.

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List of Abbreviation

HBM	Health Belief Model
SEIR	Susceptible-Exposed-Infected-Recovered
ABM	Agent-based Model
NPI	Non-pharmaceutical interventions
PHB	Preventive-health behavior
SRB	Sick-role behaviors
CDC	Centers for Disease Control and Prevention
ED	Emergency Department
OR	Odds Ratio
VSM	Value Stream Mapping
HCW	Healthcare Worker
SD	Standard Deviation
H-W	Hean-Washing

List of Assumptions

- All students are susceptible
- All students are between 20 to 24 years old
- Effective contact for influenza transmission:

  - Contact distance of susceptible and infected < 1.8m

  - Probability of transmission :$\boldsymbol{P = 1 - e^{-\lambda(t + t_2 + t_3 + \cdots)}}$

  - Lambda λ is the transmission rate for young people equal to 0.00032
- Latent period between 1 to 3 days (not infectious)
- Infection period between 3 to 6 days (infectious)
- The effectiveness of asymptomatic infection is half of symptomatic
- Thirty three per cent absenteeism for symptomatic patients
- Recovered individuals are immune for the rest of season
- No death occurs
- Hand washing effectiveness = 21%
- Vaccination effectiveness = 50%

1. Introduction

Confronting infectious diseases is a perennial problem for medicine and public health. The rapid pace of genetic mutation in influenza strains, in particular, makes developing an effective vaccine difficult. This is compounded by global warming and other changes in environment brought by human activities always provide opportunities for appearing new infectious diseases (Martens, 1999).

Influenza is subdivided into groups (A, B, and C) and sub-groups. While A and B typically cause annual influenza outbreaks, recent virulent influenza epidemics have consisted of H1N1 and H3N2, both subgroups of type A. While the general public is familiar with the influenza virus, previous work has demonstrated that they may need to be more informed about the potential severity of this disease (Karimi, Schmitt, & Akgunduz, 2016). The 1918 influenza pandemic caused an estimated 20 to 40 million fatalities, and fatalities occurred disproportionately in small children and the elderly (Christina E. Mills, Robins, & Lipsitch, 2004). These findings are borne today out as influenza outbreaks continue to be common in schools (Munoz, 2002). Individuals with compromised immune systems are also at higher risk such as Diagnosis can be complicated for older adults because their symptoms present differently (Schaffner, Chen, Hopkins, & Neuzil, 2018). Because influenza often presents with severe symptoms including fever, cough, and muscle ache (Jutel & Banister, 2013), epidemics are often marked with high levels of absenteeism and doctor's visits, even at the university level. Complications from influenza can be severe and can lead to hospitalization (Cate TR., 1987). A study in US (Molinari et al., 2007) shows influenza epidemic causes a total economic burden of $87.1 billion annually including statistical life values. While annual flu vaccination is considered to be the gold standard in controlling influenza epidemics, the effectiveness of this approach is hampered by low vaccine efficacy and relatively low levels of vaccination, particularly among young, healthy adults.

Beyond vaccination, preventive strategies can include non-pharmaceutical interventions (NPIs) like hand-hygiene, self-isolation and social distancing appeared to control influenza outbreaks. While NPIs have the potential to be effective, they are often inadequately deployed. Hashmi et al. found a research among 653 students of Massachusetts Institution of Technology (MIT) resulted in lack of practice NPIs for more than 70% of respondents and there was lack of knowledge of influenza vaccination for more than half of participants (Hashmi et al., 2018).

Mathematical models for a pandemic disease can helps policy-makers to minimize the outbreak and the cost. It enables us to analyze an infection outbreak by modelling the transmissions of infection steps which are called compartment/MSEIR models including maternally derived immunity, susceptible, exposed, infected, and recovered (Hethcore 2000). Compartment models are a very fundamental and common models that were developed in 1900 (Brauer, 2008) .Some psychological studies examined the relationship between individuals' perceptions of a disease and rates of their health behaviors (Munro, Lewin, Swart, & Volmink, 2007). And one of the psychological methods is HBM that has been used widely e.g. HIV/AIDS with condom usage (Tarkang & Zotor, 2015), and influenza with vaccination (Blue & Valley, 2002).

HBM has been studied along with simulation of influenza infection as well(Yan, Tang and Xiao, 2018; Karimi, Schmitt, & Akgunduz, 2015). This study showed the more information distribution takes place the more improvement in individuals' attitudes towards influenza will be witnessed.

In this study we conducted a survey and an information session among bachelor engineering students of Concordia University to evaluate their perceptions of influenza. Vaccination and Hand-washing were considered as preventive health behaviors, since they are known as two effective preventive behaviors. Admittedly that there exists a large body of literatures about HBM and influenza vaccination (Kang, Culp, & Abbas, 2017; Kan & Zhang, 2018). Attitude, personal responsibility, and intention of healthcare workers were considered predictor variables of hand-washing behaviour (Jenner, Watson, Miller, Jones, & Scott, 2002). Another study of hand-washing considered elementary school students and assessed the influence of an educational program on the rate of hand-washing (Morton & Schultz, 2004). But considering vaccination and hand-washing along with an educational program makes our study unique. The survey was designed based on HBM. An independent t-test verified a significant difference between treatment (information session attendants) and control groups. The logistic regression quantified the relationship between the interventions and health behaviours.

We targeted the quantity and the quality of facilities within the Hall building of Concordia University in the survey to measure if any improvement is necessary. We developed an agent based model to simulate effectiveness of students' preventive behaviors on influenza transmission based on three scenarios; baseline, control, and treatment. The results of this study may convince policy makers to consider recommendations such as increasing health education and improving lack of facilities.

2. Literature Review

We have applied three qualified models in Infection, Healthcare, and Simulation to model influenza transmission aside with health behaviors close to reality. In this chapter, we reviewed the history and outstanding studies related to these models which are named Compartmental model, Health Belief Model, and Agent based Model.

2.1. Compartmental Model

The progress in vaccination and antibiotics in 1960s, was a great hope for scientists that infection diseases can be soon eliminated; however infections have adopted and appeared in a different type (Hethcote, 2000). Thus, mathematical model grew and applied more often to study and control the disease transmission (Beck & Pauker, 1983). It has been used from the chronic diseases such as coronary heart disease to seasonal infection such as the influenza (H1N1) (Weinstein *et al.*, 1987; Coburn, Wagner and Blower, 2009). A review study about influenza outbreaks on 2014 shows majority of studies have used the mathematical model in order to forecast the dynamics of outbreak and these studies mainly aimed to show the right decision making towards the interventions (Nsoesie, Brownstein, Ramakrishnan, & Marathe, 2014).

Mathematical model can help to analyze infectious diseases transmission and control it. Accurate assumptions (considering age, culture of case study, gender, and common habits), appropriate variables and parameters, and a high quantity sample data all prepare material required for a computer simulation which can anticipate the infection behavior in reality. Compartmental/MSEIR model is the fundamental mathematical model which was developed on 20th century and it constitutes the compartments of general transfer diagram and each label is corresponding to different stage of infecting as well as Passively Immune, Susceptible, Exposed, Infected, and Recovered (Hethcote, 2000).

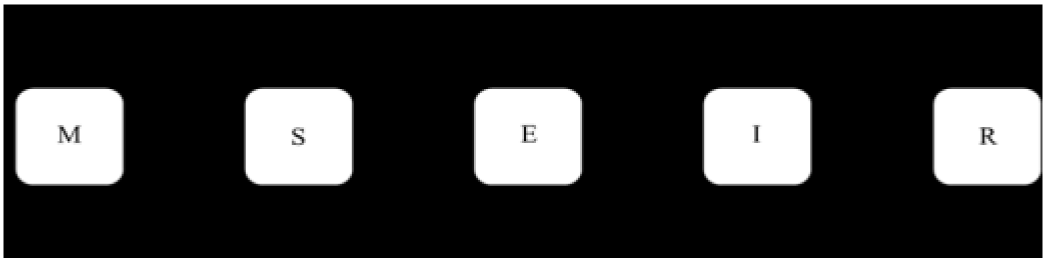

Figure 1: The Compartmental Model; MSEIR represent different stages of infection (Hethcote, 2000)

If a mother is infected, her baby is going to have some IgG antibodies which makes them passively immune and they are considered within M stage; once antibodies disappear they are susceptible (S compartment). People who have not been infected already they are susceptible at the first place. If a susceptible individual contacts infected people (considering enough number of contacts, duration of each contact, and distance) they will be transferred to exposed stage and the latent period starts; however, they cannot transmit the disease till they became infected. After infectious period they enter to recovered stage (Hethcote, 2000).

Depending on the disease and case study, different combination of labels might be considered such as MSEIR, SEIR, SIR, etc. In case of influenza between bachelor students SEIR can address the simulation's assumptions (Kraemer, 2006). For example a study of 1918 pandemic influenza using SEIR models indicates the reproductive number is not as high as other diseases which means the influenza can be controlled. This study claims the lack of vaccine and antiviral medicine along with early start of outbreak prior to diagnosis, are the reasons why the influenza is not completely controlled. (Christina E. Mills, Robins, & Lipsitch, 2004). In order to determine an infection disease within a mathematical model Kermack and McKendrick defined a concept named R_0. It represents the number secondary infected people by the first ill. If R_0>1, the outbreak occurs and if not, no infection will be spread within the target society (Kermack & McKendrick, 1927). Another study simulate pandemic influenza transmission within population of Italy based on SEIR model. This study considered different interventions including vaccination, social distancing, international flight restrictions, and antiviral medicines. Scenarios were defined based on assuming different values for the number of secondary infections as well as$R_0 = 1.4$, $R_0 = 1.7$, and $R_0 = 2$. The pick days and the number of new cases visiting clinics vary depend on R_0 (Ciofi degli Atti *et al.*,2008).

In contrast with endemic diseases, epidemic is representing infectious diseases which spread during a short period like a season or less than one year. In our study we considered influenza epidemic based on SEIR model without considering death due to the age of participants and the fact that mild influenza does not cause significant fatality between youth.

2.2. Health Belief Model (HBM)

Before the Health Belief Model appeared, the Medical Model was being used to identify some factors including social background of patients, type and duration of regimen, and severity of disease. These factors are long-lasting, persisting and unlikely to change even if any relationship between them and patients' behaviors would exist. The Medical Model is not structured in a way to motivate patients. Consequently, it is not possible to use this model with a high number of patients because various characteristics can cause a failure in therapy (Becker, 1974).

Psychologists of US health service came up with the idea of HBM in 1950s which is based on four variables namely, perceived susceptibility, perceived severity, perceived benefits of taking action and perceived barriers to taking actions (Janz & Becker, 1984).

An individual shows the right health behaviors against a disease if he realizes he is susceptible to it, if he realizes the severity of the disease and what difficulties it may bring to his life, and if he needs to believe in the benefits of the actions regarding safety. However, he needs to overcome the barriers of the protective action such as cost, pain and convenience.

Beyond these 4 criteria, Cues of Action can convince individuals to follow the heath behavior. This factor can be internal (i.e., symptoms) or external such as communication, a TV programme or a health service poster. However, these kind of cues might be easy to forget for people who never took the action. (Rosenstock, 1974). Figure.2 shows Rosenstock's definition of HBM and the relationships of variables and likelihood of action.

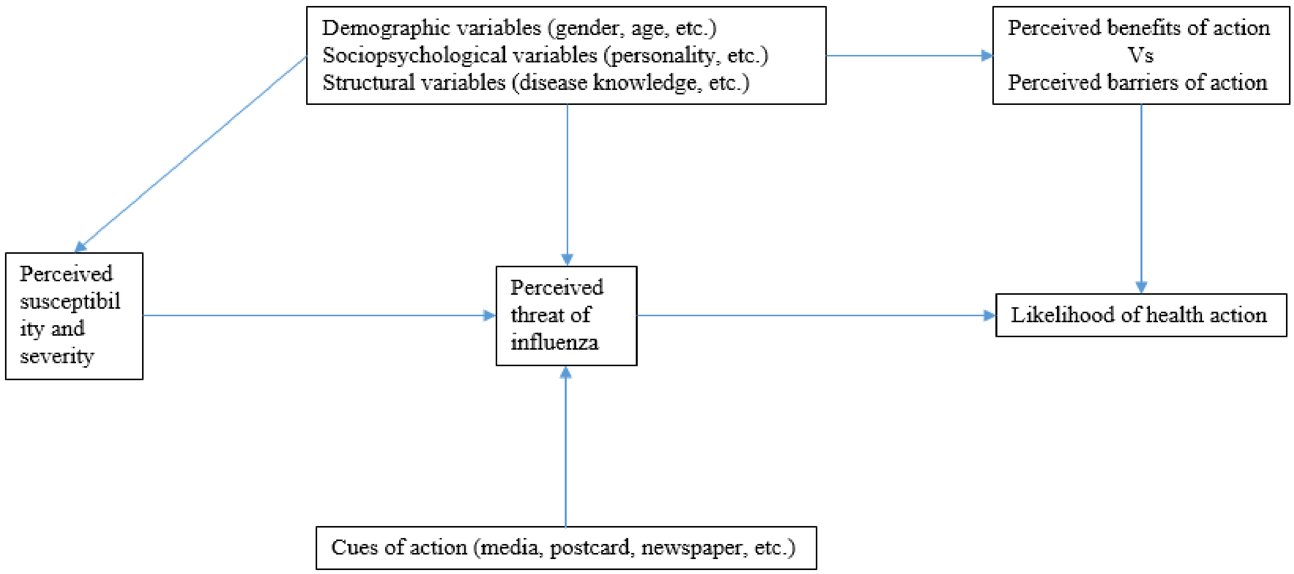

Figure 2: Health Belief Model (Rosenstock, 1974)

After all, Bandura introduced another factor named self-efficacy which identifies the confidence of an individual for taking an action or a health behavior (Bandura, 1971).

HBM was applied for various infectious disease such as HIV, Hepatitis B, Breast Cancer, and Influenza. Considering condom usage as a preventive behavior is frequent in HIV studies(Tarkang & Zotor, 2015). An HBM study about HIV between Taiwanese immigrants in USA showed self-efficacy plays the most significant role compared to other factors (Simoni, 2005). Results of The HBM study among 40 years old women and older suggests raising the programs that encourages and increases breast cancer screening (Fulton et al., 1991). Another study among 1500 health workers based on HBM identified acceptance of hepatitis B vaccination is highly correlated with the perceptions of safety and effectiveness of vaccination (Fulton, Bodenheimer, & Kramer, 1986). A research study among 199 pregnant women in 2011 showed that influenza vaccination is highly correlated with perceived susceptibility, perceived benefit of vaccination, and doctor recommendation (Gorman, Brewer, Wang, & Chambers, 2012).

HBM has been also utilised to examine cooperation of patients in order to address patient safety (Bishop, Baker, Boyle, & MacKinnon, 2015). This study showed the perception of threat and self-efficacy are correlated with applying the specific health behaviour such as vaccination and screening.

In 1984 a comprehensive literature review was done on HBM studies; 29 studies during 1974 to 1984 and a 17 studies before 1974. They were categorized to three groups; those which explored preventive-health behavior (PHB) which represents health behaviors that people follow to avoid sickness, sick-role behaviors (SRB) which shows actions an individual takes to stop progress of illness after he/she feels the symptoms, and the Clinic utilization. In this literature the significance ratios of HBM dimensions (perceived susceptibility, perceived severity, perceived benefits and barriers) were assessed and compared between studies. The level of susceptibility and severity perception correspond the likelihood of taking an action and the perception of benefits (minus barriers) indicate the type of action. Regardless of the categorization "perceived barriers" had the most significant ratio among different studies. Perceived severity was the least significant factor in every studies except studies of SRB which severity played the second most important role. In studies prior to 1974, the percentage of susceptibility was higher than the recent studies due to the fact that in early 1970 preventive behavior against diseases were more under considerations. The HBM is recommended to be educated in this study. (Janz & Becker, 1984).

Influenza was also one the diseases under consideration by researchers who works on HBM. In 2001, report of Disease Control and Prevention (CDC) says influenza vaccination has 70% to 90% influence on prevention; therefore, school and work absence and medicine consumption decreased. A study has been done with the case study of workers in a worksite which had an influenza vaccine program for free. Prior to the vaccination a questionnaire about HBM was sent to some random workers; about half of them were replied. The second postcard questionnaire was sent after the vaccination which included questions about whether they are vaccinated, if they are vaccinated by the worksite program, and how they were aware of this program. Information about participants' decision towards vaccination in the previous year were provided; so the health behavior improvement could be witnessed. In this study except 5 main dimensions of HBM, knowledge and health motivation were questioned as well. All of them had higher rate for participants who received the vaccine compared to participants who did not. This study recommends health education and increasing awareness of influenza and benefits of vaccination as well as reducing barriers. (Blue & Valley, 2002)

Hand hygiene is another behavior recommended to stop influenza outbreak. During the years 2009 and 2010 H1N1 influenza pandemic has been spreading widely and due to lack of vaccine, alcohol-based sanitizers were put in crowded spots inside institutions. The study of (Updegraff, Emanuel, Gallagher, & Steinman, 2011) indicates installing reminder signs based on HBM dimensions next to the dispensers increases sanitizers' usage. However, in this study HBMs' dimensions were modified to perceived susceptibility, social norms (defined as a belief that if a behavior is accepted by an important group of people, others may follow), consequences of behavior framed as gains, and consequences of behavior framed as losses. Each sign corresponded an HBM dimension and it included a headline like "Germs are out to get you. Get them first!" (For perceived susceptibility), and a brochure containing the details. 65 sanitizers were monitored in a university; 7 of them kept without any sign and the rest were installed randomly with one of the four sings and they were changing every three weeks. The study started at the end of September 2009. Results showed 66% increase in usage of sanitizer with the gain-framed signs as the highest significant element and 41% increase in usage of sanitizer with the susceptibility sings which was the lowest element compared to the sanitizers without any signs. The signs, in this study, as an external cues of action could associate health behavior improvement although, usage of sanitizer decreased as public interest in H1N1 (based on Google search volume) had decreased in next months.

We developed an HBM with the main four factors. And a health education program was conducted to analyze if it has any impact on students' health behaviors.

2.3. Agent Based Modelling (ABM)

Agent based modeling is a computer simulation based on the interactions between agents. The further details are provided the more reliable predictions can be resulted from a simulation of nature. Agent based modeling is well-adopted to the nature and its constraints (Gilbert & Terna, 2000). Various characteristics are possible to be defined for agents and this utilization enables us to model human behaviours and their interaction. An ABM usually includes these three items (Macal & North, 2010):

- The agent sets; with their specific behaviours
- The relationships; between agents which define interactions
- The environment; that can be involved in interactions

The type of interactions, distance, and duration of contacts may cause a disease transmission from an infected individual to a susceptible one. Since agent based simulation focuses on individualism, characteristics of each agent (or an agent set) need to be coded separately.

It can be a substitute for optimization in heterogeneous environment. Constraints can be defined as some rules that should be addressed in agents' interactions (Barbati, Bruno, & Genovese, 2012). A study conducted a great comparison between old simulation approaches and ABM using ARENA (Borshchev & Filippov, 2004). This study used some sample simulations of Discrete Event and System Dynamic to transfer them into ABM and they have achieved the same results; however, this study suggests that ABM is not necessarily a substitute for traditional simulations but it is recommended for more complex problem that are involved with active objects such as human, vehicle, and animal.

ABM has been widely utilized in economic since it is a suitable method in order to assess complex and stochastic behavior of agents (Billari, Fent, Prskawetz, & Scheffran, 2006; Conte, Hegselmann, & Terna, 1997). In a review study of ABM in business, application of ABM were divided into four areas; flows like costumer flow management, markets, organization, and diffusion of innovation. Emergence phenomena is predictive in these four areas and the advantage of ABM is capability of Emergence phenomena simulation. Emergence phenomena says 'the whole is greater than the sum of its parts' meaning that the whole system has a characteristic that cannot be seen in the parts; like a traffic jam that may grow in the opposite direction of the car. Flexibility and picturing the system naturally are the other benefits of ABM (Bonabeau, 2002).

Generally, complicated and detail oriented simulations are used in sociology which is based on interactions between variables. This is a necessary fact when details are so important to be as close as possible to reality like a flight simulator. However, if a deep understanding of fundamental processes are the goal, ABM is an applicable simulation that enables us to define assumptions simply (Macy & Willer, 2002).

Application of ABM in healthcare can be divided to three different areas (Barnes, 2012):

- Healthcare delivery; that a place such as emergency room is simulated considering patients and health workers' decision making.
- Epidemiology; that simulate the outbreak of an infection in a society
- Healthcare economics; that target the customising the expenses which are results of different decision making by healthcare system

In complex adoptive system, it is hard to have a perfect understanding of consequence in the whole system by considering individuals' behaviours e.g. Emergency Department (ED) (Kanagarajah et al. 2006). ABM is applicable for complex adoptive systems it is possible to improve the health service delivery. As an example, in order to improve Operation Room (OR), a study integrated Value Stream Mapping (VSM) and ABM to simulate different alternatives and the result proved this simulation can improve decision making (Xie & Peng, 2012).
An emergency department of a hospital in Winnipeg, Canada was targeted for ABM simulation using C++. Results suggest following four policies for emergency departments. First, nurses ask anyone who has influenza-like illness symptoms. Second, due to high rate of close contact masking for HCWs are necessary. Third, moving all the patients with influenza-like illness symptoms into another area and splitting them from other patients. Finally, sending HCWs to home once they get ill (Laskowski et al., 2011).

In 1976, Elveback used agent based simulation for modeling 1918 pandemic influenza amongst one thousand people. Transmission risk was defined based on the contact times between people. Different constraints also were considered in this study such as quarantine of students and contacts reduction (Elveback et al., 1976). This study was a pioneer in simulation of influenza and many relevant studies followed the similar path afterwards. Connie Carpenter has developed an Agent-Based Simulation of 1918 influenza epidemic by considering people's characteristic and behaviors, their movements, and seasonal structure of community. This study took the advantage of ABM and considered different interaction rate between family members compared to strangers. Moreover, it evaluates a hypothetic scenario which shows 18% more fatality could had been witnessed if 1918 influenza outbreak would had happened in summer rather than winter. Higher rate of trade activities such as traveling was considered in this scenario (Carpenter & Sattenspiel, 2009).

Two significant economic variables in a healthcare system are waiting time and using physicians which are considered in Kanagaraja et al. study (Kanagarajah et al. 2006). They applied ABM in order to find a balance between quality of healthcare service and economic incentives. Possibility of different remedies were simulated such as using on-call physicians, and minimizing the time that a physician spends with each patient.

We developed ABM in MATLAB 2014 based on SEIR model and HBM. We run this model for 119 days equal to one semester considering each student is assigned to specific courses. They hang around in lounges, library, outside, or etc. after or before their classes and they are distributed based on their responses in survey. Their interactions may or may not cause infection transmission.

3. Data

In order to find sample size there are different formulas depending on what parameters are known; since in this study population standard deviation is unknown, Cochran's formula can provide us an estimation of sample size (Bartlett, Kotrlik, & Higgins, 2001):

$$N = [p(1-p)] * [\left(\frac{Z}{E}\right)^2]$$

Where:

p = 72.9% percentage of students who wash their hands (Anderson, Warren, Perez, Louis, & Phillips, 2008)

Z = 1.96 for 95% confidence level

E = 6.5% margin of error (Press, 2016)

N = 179.63 or 180 which is approximate sample size for each group, however, it is recommended to consider Cochran's correction formula for smaller population size.

$$N_1 = \frac{N}{1 + (\frac{N}{Population})}$$

The number of all students considered 4800, therefore $N_1 = 174$ is a fine estimation for sample size. The value of "p" represents the part of population that contribute in hand-washing which for treatment groups, has not been assessed before. We did not consider "p" of vaccination since most of questions in our survey are based on hand-washing.

We asked different engineering professors to allocate a part of their session for our survey. However, three of them replied and confirmed co-operating with our study and these resulted in 115 students for treatment group and 127 students for control group.

3.1. Method

We conducted a cross sectional survey among engineering students at Concordia University. Students were divided into two different groups. The survey instrument was administered to both the control group and treatment group. The treatment group participated in a health education program prior to filling in the survey. Questions were based on HBM variables and their internal consistency has been measured by Cronbach's alpha.

Identifying the influence of a health education program on health behaviour, assessing the quality of on-campus hand-washing facilities, and investigating the relationship between the HBM criteria and the interventions (hand-washing and vaccination), are objectives of data analysis. After removing outliers, a t-test was conducted to assess the difference in results between the two groups. Descriptive statistics were used to assess the facility questions, and logistic regression was used to investigate the relationship between HBM variables and the targeted preventive behaviours.

3.2. Survey Instrument and Education

The survey was distributed to 242 student volunteers taking ENGR 392, ENGR 201, and MECH 352 during winter 2017 and spring 2018. Ethics approval was obtained from Concordia's University Human Ethics Review. Since the surveys were anonymous, students were asked not to respond if they had already done so in another class. An oral consent were received before starting the program. 127 students were in the classes assigned to the control groups while the remaining 115 participated in the education program. The survey included 26 questions based on HBM variables; perceived susceptibility to influenza, perceived severity of influenza, perceived benefits of hand-washing, perceived barriers of hand-washing, perceived benefits of vaccination, and perceived barriers of vaccination. All the questions were divided to these six variables. A five-category Likert scale consisting of strongly disagree, disagree, neutral, agree, and strongly agree was used for the first 13 questions while never, rarely, sometimes, often, and always was used for the remaining 13 questions.

The education program was a fifteen minutes presentation delivered by a health promotion specialist from Concordia University health service. The training aimed to increase student knowledge about influenza and how to improve health behaviors (vaccination and hand-washing). The presentation emphasized health behaviors for both susceptible and infectious people, the consequence of being infected, and the necessity of vaccination and hand-washing in order to avoid infection transmission.

3.3. Data Analysis

After collection, data was entered into Microsoft Excel 2013. Responses of 5 participants from the control group and 5 participants from the treatment group had a Z-score greater than 2.68. These were deemed outliers and removed. Therefore, the number of valid respondents were 232. The mean and the standard deviation were calculated for all the questions for both treatment and control group. We clustered the question into 6 groups based on HBM variables. Cronbach's alpha was calculated to check the internal consistency for groups with more than 2 questions. Independent-samples t-test showed the effectiveness of education on student perceptions. Logistic regression quantified the relationship between HBM variables and preventive behaviours. Odds-ratio (OR) are interpreted when there was strong evidence of a relationship between health belief and behaviour ($p\text{-value} < 0.05$).

3.4. Results

3.4.1. Descriptive statistics

The majority of participants were male (76 per cent). The gender ratio was similar among the treatment and control group, with 7% more women in the control groups. 76% of respondents were between 20 to 24 years old. 6% of participants (14 students) reported having received influenza vaccination during the 2017-2018 season. 86% of students reported washing hands often or very often to prevent disease.

3.4.2. Internal consistency

Questions were designed to represent the HBM variables; therefore, internal consistency among questions belonging to each variables should be calculated. All the variables consists of more than two questions except perceived benefits of vaccination and perceived barriers of vaccination which each of them included only one `question. Table 1 displays the calculated mean and SD per each HBM variable using the scaled answer from strongly disagree (1) to strongly agree (5). Where more than 2 questions pertained to the same variable, Cronbach's alpha was calculated and is also displayed. As Table 1 displays, alpha values were between .6 and .77 which demonstrates a moderate to high degree of internal consistency among questions (Tavakol & Dennick, 2011). Table 1 includes examples questions.

Table 1: Internal consistency and t-test; Means are calculated based on responses. A response of strongly disagree corresponds to a 1, while strongly agree corresponds to a 5. Internal consistency was calculated using Cronbach's alpha

	Control: Mean SD ---------- Alpha	**Treatment:** Mean SD ---------- Alpha	t P-value
Perceived Susceptibility to Influenza: Questions 1 to 4	3.26 1.14 ---------- 0.60	4.22 0.76 ---------- 0.72	7.43 0.000***
Perceived Severity of Influenza: Questions 15 to 17	2.95 1.17 ---------- 0.76	3.39 1.15 ---------- 0.77	2.84 0.005**
Hand-Washing Perceived Benefits: Questions 14 and 18 to 22	3.56 1.12 ---------- 0.63	3.90 1.04 ---------- 0.66	2.32 0.021*
Hand-Washing Perceived Barriers: Questions 7 to 13 and 23 to 26	1.37 0.67 ---------- 0.64	1.59 1.02 ---------- 0.60	1.94 0.054
Vaccination Perceived Benefits: Question 6	2.78 1.08 ---------- NA	3.40 1.12 ---------- NA	4.27 0.000***
Vaccination Perceived Barriers: Question 5	2.10 1.23 ---------- NA	1.99 1.31 ---------- NA	0.64 0.5

Note: The significant difference between treatment and control group can be recognized by P-value where *P<0.05, **P<0.01, and ***P<0.001.

3.4.3. The independent-samples t-test

In addition to mean and standard deviation, a t-test could bring more evidence to find the significant difference between the two groups. Table 1 displays the mean, the standard deviation, the value of the t, and the p-value related to the t-test for considered HBM variables. The p-value for all of the variables are <0.05 except for perceived barriers of interventions. The health education session had a statistically significant effect on student perception of susceptibility to influenza, severity of influenza, and benefits of hand-washing and vaccination. The majority of questions related to perceived barriers of interventions were about on-campus facilities. Student responses indicate that hand-washing facilities present a barrier to combatting influenza and general infection control. Improving these facilities may increase preventive behaviours among students.

3.4.4. Health facilities evaluation

Nine questions were designed to target on-campus facilities; Table 2 shows that the average of responses from the control and treatment groups indicate that health and hand-washing facilities on campus are insufficient. The hypothetic problems that were asked in the survey were about hand-drying facilities like lack of towel papers and high-power hand dryers and the average responses are showing low level of fulfilment. Since drying is considered as an effective part of contaminant removal, (N, Atul, Renuka, & V, 2012) it is recommended for Concordia policy-makers to place towel papers on bathroom along with appropriate hand-dryers.

Table 2: Quality of facilities within campus

	Control: Mean SD	**Treatment:** Mean SD
Question 5, 7 to 13, and 23	2.08 1.19	1.96 1.51

3.4.5. Logistic Regression

We included two other questions regarding frequency of hand-washing and vaccination applied by students in order to prevent influenza. Responses of "never" and "sometimes" were coded as zero while "often", "very often" and "always" were coded as one. Logistic regression has been conducted based on these interventions in respect of HBM variables.

3.4.5.1. Hand-washing and Health Belief Model

Table 3 displays OR and p-value of logistic regression. Hand-washing of treatment group is highly correlated with all the applicable variables except perceived severity of influenza. The OR for hand-washing in respect of perceived susceptibility to influenza is 2.03 with the p-value < 0.05. It means an individual with high perceived susceptibility to influenza and low level of perception in other variables is 2.03 times more likely to wash their hand compared to an individuals with low perception in all variables. The OR = 2.06 with p-value < 0.05 represent the same relationship between probability of practicing hand-washing and perceived benefits of hand-washing. Hand-washing is inversely correlated with perceived barriers of hand-washing; participants with high perceptions of barriers were half as likely to wash their hands as participants with low perceptions of barriers of hand-washing.

In the control group, hand-washing is highly correlated with perceived benefits and barriers of hand-washing. For the control group, the OR of hand-washing with respect to the perceived benefits of hand-washing is 2.13. This means that the higher the perceptions of benefits of hand-washing, the more hand-washing is likely to be applied. In contrast, the OR of hand-washing and perceived barriers of this intervention was 0.49, representing a reduction in hand-washing related to higher perceived barriers of hand-washing.

Table 3: Logistic regression of HBM variables in respect to Hand-washing

HBM \ Preventive Behaviours	Hand-Washing Treatment		Hand-Washing Control	
	P-value	Odds-ratio	P-value	Odds-ratio
Perceived Susceptibility to Influenza Strongly Disagree, Disagree Neutral, Agree, Strongly Agree	0.03*	2.03	0.07	1.47
Perceived Severity of Influenza Strongly Disagree, Disagree Neutral, Agree, Strongly Agree	0.5	1.16	0.15	1.37
Perceived Benefits of Hand-Washing Strongly Disagree, Disagree Neutral, Agree, Strongly Agree	0.009**	2.06	0.001**	2.13
Perceived Barriers of Hand-Washing Strongly Disagree, Disagree Neutral, Agree, Strongly Agree	0.01*	0.5	0.003**	0.49

Note: *P<0.05, **P<0.01, ***P<0.001
NA = Not Applicable.

3.4.5.2. Vaccination and Health Belief Model

The relationships between influenza vaccination and HBM variables are indicated in Table 4. The p-value is >0.05 for vaccination with respect to all HBM variables; although for the control group we have witnessed correlations between vaccination and perceived benefits of vaccination (OR=1.44) and perceived barriers of vaccination (OR=0.56). Likelihood of vaccination among students with high perceived benefits of vaccination increases while this intervention decreases with higher perceived barriers of vaccination.

Table 4: Logistic regression of HBM variables in respect to Vaccination

HBM \ Preventive Behaviours	Vaccination Treatment		Vaccination Control	
	P-value	Odds-ratio	P-value	Odds-ratio
Perceived Susceptibility to Influenza Strongly Disagree, Disagree Neutral, Agree, Strongly Agree	0.4	1.2	0.14	1.28
Perceived Severity of Influenza Strongly Disagree, Disagree Neutral, Agree, Strongly Agree	0.2	1.25	0.50	0.89
Perceived Benefits of Vaccination Strongly Disagree, Disagree Neutral, Agree, Strongly Agree	0.15	1.36	0.04*	1.44
Perceived Barriers of Vaccination Strongly Disagree, Disagree Neutral, Agree, Strongly Agree	0.06	0.7	0.001*	0.56

Note: *P<0.05, **P<0.01, ***P<0.001
NA = Not Applicable.

3.4.6. Discussion

We focused on vaccination and specifically hand-washing as two known effective preventive behaviours among young adults (Blue & Valley, 2002; Ryan, Christian, & Wohlrabe, 2001). The health education treatment was based on these behaviours and aimed to increase by focusing on effectiveness of these behaviours in preventing influenza. The health promotion specialist demonstrated effective hand-washing, showed students how easily it is to become infected with influenza by touching the face and the fact that frequent and appropriate hand-washing can decrease the feasibility of catching the disease. He also talked about the benefits of flu vaccination. Since we had limited age diversity and the majority of participants were male we did not analyse age and gender.

Cronbach's alpha > 0.6 indicated internal consistency between questions for hand-washing related to each of HBM variables. Perceived benefits and barriers of vaccination each had one question.

Several factors likely influenced the students' ratings of facilities. These stem from factors both local to the university and those due to provincial law. Many bathrooms at Concordia, and all bathrooms in the engineering building, lack paper towels. Municipal public health agencies review and approve bathroom facilities for adequate hand drying capacity based on the number of paper towel holders and the number of hand dryers. Including a paper towel holder allowed the engineering building bathroom plans to be approved with only one dryer, resulting in inadequate drying facilities since the paper towel holders are never filled. Thus, students are left to choose between wet hands and not washing hands.

The barriers to vaccination, on the other hand, are a result of provincial law. In 2015, the Quebec National Assembly passed Bill 20, which among other things restricted the ability of publicly funded medical clinics to charge for services (Bill 20, 2015). This change was aimed at preventing abusive fees. In addition, Quebec offers flu vaccine only to immune compromised individuals or those who come in close contact with them. An unintended consequence of these two policies is that university health clinics can only vaccinate a handful of students, and can no longer provide at-cost vaccination services for those who do not fall into the free category, which provided students both ease of access and lower prices. Now, non-eligible students must access flu vaccines at private clinics. Perhaps most significantly, by recommending and offering low-cost vaccination the university health clinic provided a strong signal that vaccination is necessary and safe. The analysis result suggests that health education can improve student perceptions about influenza and preventive behaviours. It may also increase the rate of preventive behaviours among participants. The p-value of the t-tests were < 0.05 for every variable except perceived barriers of hand-washing and vaccination. The barrier questions were mostly about on-campus facilities. For both the treatment and control groups, participants did not find on-campus vaccination convenient, were not satisfied by the hand-dryers on-campus, and indicated a lack of paper towels in the bathrooms.

The logistic regression results (Table 3) showed that in the treatment group, perceived susceptibility to influenza, perceived benefits and barriers to hand-washing are correlated to hand-washing. Higher perceptions of susceptibility and benefits resulted in higher hand-washing while lower perceived barriers resulted in higher hand-washing. The p-value of perceived susceptibility to influenza with respect to hand-washing in the control group was > 0.05, meaning that we cannot reject the null hypothesis that there is no relationship between the variable and the preventive behaviour. However, the perceived benefits and barriers of hand-washing in the control group have the same relationship with hand-washing. Table 4 shows the p-value > 0.05 for all variables with respect to vaccination for the treatment group. In the control group perceived benefits and barriers of vaccination are significant predictors of vaccination.

Potential limitations of this analysis include relatively few questions regarding vaccinations, due to time constraints. Classes were randomly assigned to either the control or treatment group, and different number of students in each class resulted in unequal numbers of participant for each group. The majority of participants were male is another potential source of bias.

The results of this analysis can be used in a simulation which models influenza transmission and participant beliefs in a community setting.

4. Modeling Influenza

Our model has three main criteria; students' interactions, influenza transmission, and preventive behaviors. These criteria are built based on Agent Based Modeling, Compartment / SEIR Model, and Health Belief Model respectively. In this chapter we elaborate the SEIR model and relevant formulas that are considered for influenza transmission between agents. Then, we demonstrate how our data analysis of preventive behaviors can involve in our simulation and create two scenarios based on the control group and the treatment group.

4.1. Model Development and Assumptions

As mentioned on Compartment model section, SEIR is relatively an appropriate approach to be considered for influenza transmission (Kraemer, 2006).

All agents are considered susceptible from the beginning of simulation except some initial infected individuals. If a susceptible person has effective contacts with infected ones and the infection transmission occurs, the susceptible person enters either latent or incubation periods which are not infectious. Subsequently, he/she enters into either symptomatic or asymptomatic infectious periods and eventually he/she recovers and never get infected again during the season. The duration of latent, incubation, symptomatic, and asymptomatic periods are randomly assigned to students based on the estimations in the study of Longini (I. M. Longini, 2005).

Table 5: Duration of Latent and Infection Periods with their distribution probability among people (I. M. Longini, 2005)

		Latent	Period	
Number of Days (Possibility)	1 (30%)	2 (50%)	3 (20%)	_
		Infection	Period	
Number of Days (Possibility)	3 (30%)	4 (40%)	5 (20%)	6 (10%)

Table 6: Occurrence possibility of symptomatic and asymptomatic infection and their effectiveness (I. M. Longini, 2005)

	Symptomatic	Asymptomatic
Possibility	67%	33%
Effectiveness	100%	50%

Table 5 shows the number of days of latent and infection periods that we considered in our simulation. Once the agent enters the Exposed or Infected compartments the number of days for latent and infection period are assigned randomly based on distribution shown in table 5. And the possibility of having symptomatic or asymptomatic infection is calculated before entering in the infected compartment based on the possibility of occurrence in table 6. If an individual is assigned as an asymptomatic infected he/she has 50% less effective compared to symptomatic infected students. Based on Longini study 33% of infected individuals prefer to stop their daily activities as well as attending to classes (Ira M Longini, Halloran, Nizam, & Yang, 2004).

The transmission rate from Susceptible to Exposed is called Horizontal Incident which is based on effective contacts between susceptible individuals and infected ones. Moving towards Recovered compartment from the Exposed stage, depends on two factors; the average time that each stage may last and the number of individuals within each compartment (Hethcote, 2000).

Relevant notations are shortly defined in table 7:

Table 7: Summary of mathematical notation

S(t)	Number of susceptibles at time t
E(t)	Number of exposeds at time t
I(t)	Number of infectives at time t
R(t)	Number of recovereds at time t
s, e, i, r	Fractions of the total population in the above labels
N	Total population
β	Effective contact rate
R_0	Basic reproduction rate

The horizontal incidence shows infection rate due to interactions between infected and susceptible individuals. Beta β is the average number of effective contacts per unit time, so by multiplying fraction of infected people to β, average number of contacts per unit time can be calculated (βI/N). Thus, S(βI/N) = βNis indicates the number of new cases per unit time where s = S(t)/N, e = E(t)/N, i = I(t)/N, and r = R(t)/N.

In order to mathematically calculate the Horizontal Incident an "effective contact" needs to be defined. Effective contacts can happen in a specific distance from the infected individual (Brankston G, 2007). Having a contact within a 1.88 meter radius for a period of time "t" per minutes with an infected person can cause infection transmission with the probability of p:

$$P = 1 - e^{-\lambda t}$$

Then, $e^{-\lambda t}$ can be called propability of survival which is representing the situation that a person has effective contacts but no infection occurs. Lambda λ is the transmission rate that is estimated by Haber (Haber et al., 2007). The value of lambda differs based on the age of infected and susceptible people and it is between 0.00029 and 0.00102. In our case it is equal to 0.00032 because all our agents are young adults.

Since any susceptible person can be in contact with more than one infected person during the day, this formula can be extended to:

$$P = 1 - e^{-\lambda(t + t_2 + t_3 + \cdots)}$$

However there are other factors that play roles on infection transmission such as humidity, ventilation, and temperature but the situation in a university setting is almost constant in every sub locations.

After evenings and during weekends are periods that students are out of campus and their infection probability (table 8) can be estimated based on the average duration of contacts and average number of contacts between susceptible and infected individuals within the community in different age groups (Haber et al., 2007).

Since our survey had been conducted among undergraduate engineering students, we assumed all the same age group and the same field of study (engineering) for all the agents. University professors and staff are not considered. Two kinds of locations are assumed for students which are classes and general locations such as corridors and bathrooms. Agents' behaviors are a function of their location. Moreover, their courses and their classes are assigned to them randomly and based on the average number of credits that an undergraduate engineering student is required to apply each semester.

Table 8: Estimation of average number of contacts and average duration of contacts per minutes (Haber et al., 2007)

	Susceptible Age Groups			
Infected Age Groups	0-4	5-18	19-64	>64
0-4 Number of contacts	2.6	1.3	0	0
0-4 Ave duration of contacts per minutes	120	60	120	60
5-18 Number of contacts	1.3	2.6	0	0
5-18 Ave duration of contacts Per minutes	60	120	120	60
19-64 Number of contacts	0	0	2.6	2.6
19-64 Ave duration of contacts Per minutes	120	120	120	120
>64 Number of contacts	0	0	2.6	2.6
>64 Ave duration of contacts Per minutes	60	60	120	120

4.2. Modelling Preventive Behaviors

There are several preventive behaviors that are studied in various ways. For instance, the challenge of using high dose influenza vaccine has been evaluated for elderlies (Schaffner, Chen, Hopkins, & Neuzil, 2018). Social distancing is another example of behavior towards reducing the influenza outbreak that is recommended to be encouraged by media publicity (Yan et al., 2018). Hand-washing as an effective behavior for minimizing the infection transmission, has been widely studies within the healthcare settings (Lankford *et al.*, 2003; Pittet, 2001).

Considering two strategies (vaccination and hand-washing) together with an education program along with evaluating the health facilities within the campus make our study unique and specifically useful for improving university health policies. The data analysis of the students' surveys help us to understand students' perception about influenza, vaccination, and hand-washing. We modeled their preventive behaviors intervention based on their perceptions from Influenza.

In order to add preventive behaviors interventions into our simulation of influenza transmission we used the logistic regression. Our logistic regression is based on the preventive behaviors (dependent variables) and HBM variables (independent variables), and correlations between them are shown on Tables 3 and 4. Odd ratios determine the correlations' strength considering p-value <0.05. The occurrence of hand-washing and vaccination is either one or zero but the distribution of their iterations vary from low influenza perception to high influenza perception. The logistic regression principal formula helps us to calculate the probability of preventive behaviors based on students' perceptions:

$$P = \frac{e^{\beta_0+\beta_1 x_1}}{1+e^{\beta_0+\beta_1 x_1}}$$

The β_0 is the constant coefficient and the β_1 is the Fico Score coefficient which are provided in the result table of logistic regression using Excel 2013. The x_1 is the Credit Score that has been chosen by students in the survey. It can be one, three or five; one is corresponding to options 1 and 2, three is corresponding to 3, and five is corresponding to 4 and 5 based on the 5 options provided in the survey. The value of x_1 is determined and assigned to agents based on the students' answers distributions. Table 9 indicates β_0, β_1, and x_1 distributions, where there are a significant correlations between preventive behaviors and HBM variables for both groups.

Table 9: Logistic regression coefficients and distribution of credit scores

		Treatment Group			Control Group		
		β_0	β_1	x_1 $(Probability)$	β_0	β_1	x_1 $(Probability)$
Vaccination	Perceived Susceptibility	–	–	–	–	–	–
	Perceived Severity	–	–	–	–	–	–
	Perceived Benefits	–	–	–	-1.6515	0.3670	1 (33%) 3 (42%) 5 (25%)
	Perceived Barriers	–	–	–	0.9837	-0.5712	1 (37%) 3 (29%) 5 (34%)
Hand-washing	Perceived Susceptibility	-1.0656	0.7079	1 (3%) 3 (6%) 5 (91%)	–	–	–
	Perceived Severity	–	–	–	–	–	–
	Perceived Benefits	-0.6042	0.7264	1 (10%) 3 (20%) 5 (70%)	-1.8448	0.7602	1 (4%) 3 (4%) 5 (92%)
	Perceived Barriers	3.2176	-0.5555	1 (43%) 3 (16%) 5 (41%)	3.4992	-0.6972	1 (50%) 3 (27%) 5 (23%)

Note: *P<0.05, **P<0.01, ***P<0.001

Probability of behaviors is calculated for the variables that has correlations with the desired behaviors. Based on the data analysis vaccination has correlations with perceived benefit of vaccination and perceived barriers to vaccination for the control group and no correlation was witnessed between this behavior and the treatment group perceptions. Hand-washing has correlation with perceived benefits of hand-washing and perceived barriers to hand-washing for the control group. In case of the treatment group, this behavior has been correlated with perceived susceptibility, perceived benefit of hand-washing, and perceived barriers to hand-washing for the treatment group. During the simulation process, the average of probabilities related to a specific behavior for both groups are calculated which effects the probability of influenza transmission. The effectiveness of hand-washing is considered 21% on respiratory illnesses referring the result of a meta-analysis (Aiello, Coulborn, Perez, & Larson, 2008).

Estimating vaccination effectiveness depends on many variable such as age of case study, considering laboratory confirmed cases or clinical confirmed cases; based on a review study it can varies from 19% to 67% for healthy adults. Thus, we consider 50% effectiveness for the simulation purpose (Manzoli et al., 2012).

Table 10 and 11 show the probability of preventive behaviors' occurrence considering combinations of different values for x_1 in respect to HBM variables.

Table 10: Probability of hand-washing for the treatment group derived from the survey

Perceived Susceptibility(1)	Perceived Benefits(2)	Perceived Barriers(3)	$P_{(1)}$	$P_{(2)}$	$P_{(3)}$	$P_{(Ave)}$
1	1	1	41%	53%	93%	63%
1	1	3	41%	53%	83%	59%
1	1	5	41%	53%	61%	52%
1	3	1	41%	83%	93%	72%
1	3	3	41%	83%	83%	69%
1	3	5	41%	83%	61%	62%
1	5	1	41%	95%	93%	77%
1	5	3	41%	95%	83%	73%
1	5	5	41%	95%	61%	66%
3	1	1	74%	53%	93%	74%
3	1	3	74%	53%	83%	70%
3	1	5	74%	53%	61%	63%
3	3	1	74%	83%	93%	84%
3	3	3	74%	83%	83%	80%
3	3	5	74%	83%	61%	73%
3	5	1	74%	95%	93%	88%
3	5	3	74%	95%	83%	84%
3	5	5	74%	95%	61%	77%

5	1	1	92%	53%	93%	80%
5	1	3	92%	53%	83%	76%
5	1	5	92%	53%	61%	69%
5	3	1	92%	83%	93%	90%
5	3	3	92%	83%	83%	86%
5	3	5	92%	83%	61%	79%
5	5	1	92%	95%	93%	94%
5	5	3	92%	95%	83%	90%
5	5	5	92%	95%	61%	83%

In Table 5 the first three columns shows the value of x_1 and the $P_{(1)}$, $P_{(2)}$, and $P_{(3)}$are calculated based on logistic regression formula for Perceived susceptibility, benefits and barriers respectively. The $P_{(ave)}$ is the average of these three probabilities which correspond the possibility of washing hand for a person based on his/her response (x_1).

Because the perceived barriers has a reverse relative to the preventive behavior, the lower x_1 results in higher hand-washing probability. Consequently, the highest probability is derived from the combination of x_1=5 for perceived susceptibility and benefits and x_1=1 for the perceived barriers which results in $P_{(ave)}$= 94%.

Table 11: Probability of vaccination and hand-washing for the control group derived from the survey.

Vaccination					Hand-washing				
Perceived Benefits(1)	Perceived Barriers(2)	$P_{(1)}$	$P_{(2)}$	$P_{(Ave)}$	Perceived Benefits(3)	Perceived Barriers(4)	$P_{(3)}$	$P_{(4)}$	$P_{(Ave)}$
1	1	22%	60%	41%	1	1	25%	94%	60%
1	3	22%	33%	27%	1	3	25%	80%	53%
1	5	22%	13%	18%	1	5	25%	50%	38%
3	1	37%	60%	48%	3	1	61%	94%	78%
3	3	37%	33%	35%	3	3	61%	80%	71%
3	5	37%	13%	25%	3	5	61%	50%	56%
5	1	55%	60%	57%	5	1	88%	94%	91%
5	3	55%	33%	44%	5	3	88%	80%	84%
5	5	55%	13%	34%	5	5	88%	50%	69%

Table 6 has the same content as table 5 but for both preventive behaviors. The logistic regression results showed that vaccination has correlation with perceived benefits and barriers only for the control group; however, the information session for the treatment group, was mostly allocated to hand-washing behavior.

5. Influenza Simulation

We have developed a simulation, flexible with the number of all students, the number of initial infected, the number of rooms, the number of general locations (like corridors, lounges), and the value of Lambda λ. These are the inputs that prompted users to add their desire numbers. Considering a university building, the numbers we have chosen are 4800 students with 5 initial infected individuals between them, 150 rooms (which includes all classes and labs) and 80 general locations and the value of λ is 0.00032 for our target age group based on study of Haber (Haber et al., 2007).

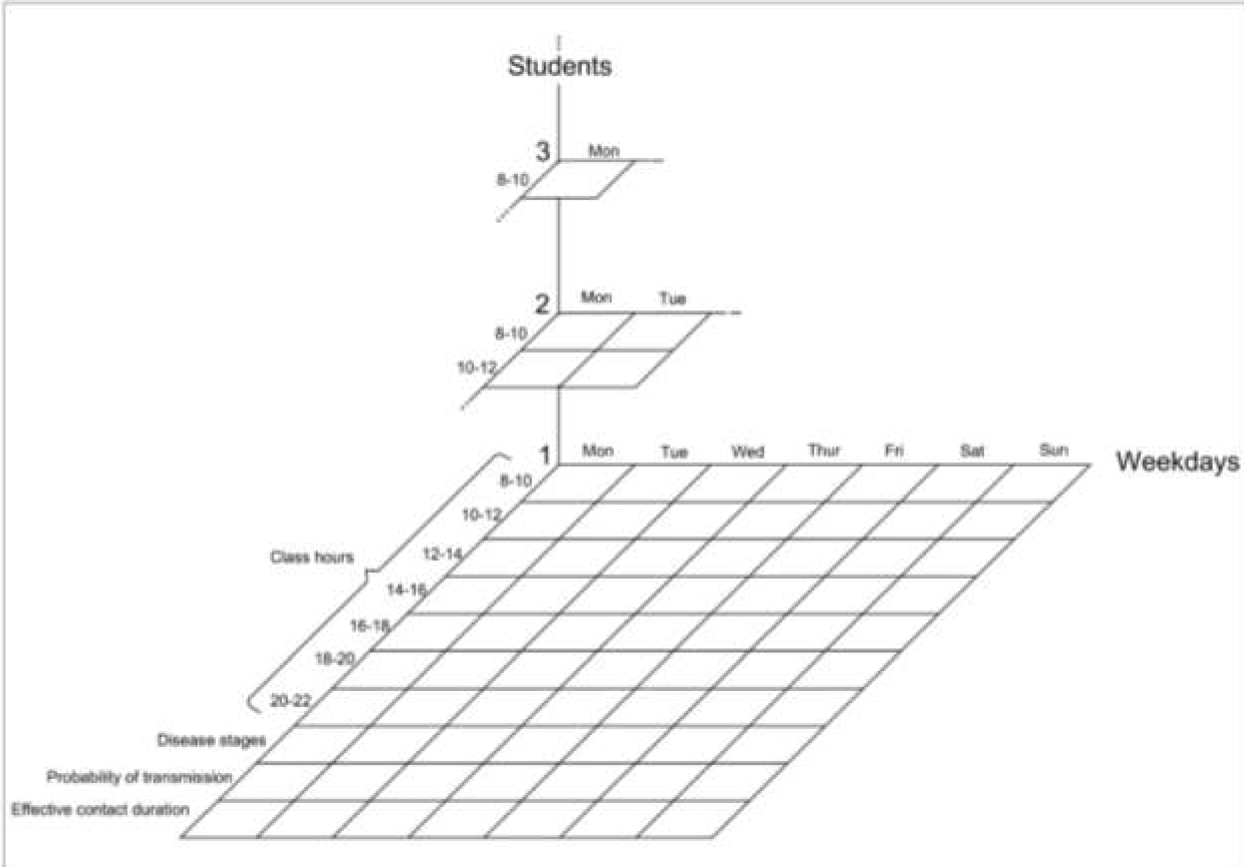

Figure 3: The main simulation matrix using MATLAB 2014

Total number of students, the number of classes, and general locations were based on an estimation of Hall-building of Concordia university.The initial number of infected individuals between 0.01% to 0.12% of total population results in the secondary infection(R_0) greater than one(Guo et al., 2015); in our case considering initial infection equal to 5 people (0.1% of population) gave us the target R_0.

After entering the inputs a 3x3 matrix (figure 3) is built; the X axis shows weekdays, the first seven row of Y axis shows timelines, the eighth row represents the student's disease compartment, the ninth row shows the probability of catching influenza based on the tenth row which is duration of effective contacts during that day, and the Z axis shows students.

Based on the average number of credits that an undergraduate engineering student is required to pick, 8 classes are assigned to each students randomly. Other locations are assigned to students randomly every week.

Table 12 represents a sample of X and Y axis of first two week for a student. The number of classes are between 1 and 10 and general locations are determined from 11 to 15.

Table 12: Axis X and Y of main matrix for student #1 for two weeks

Days (week-1)	Mon	Tue	Wed	Thurs	Fri	Sat	Sun
8-10	12	12	10	11	10	0	0
10-12	14	11	12	10	11	0	0
12-14	13	9	14	12	11	0	0
14-16	5	14	13	12	10	0	0
16-18	2	12	11	13	14	0	0
18-20	14	12	2	11	12	0	0
20-22	12	13	14	13	14	0	0
Disease Stages	0	0	0	0	0	0	0
Probability of Transmission	0	0	0	0	0.0438	0	0
Effective contacts duration	0	0	0	0	140	0	0
Days (week-2)	Mon	Tue	Wed	Thurs	Fri	Sat	Sun
8-10	15	14	10	14	10	0	0
10-12	13	11	13	10	14	0	0
12-14	14	9	14	13	14	0	0
14-16	5	15	12	13	10	0	0

16-18	2	11	12	14	11	0	0
18-20	14	12	2	11	11	0	0
20-22	13	14	11	12	11	0	0
Disease Stages	1	1	1	1	1	1	2
Probability of Transmission	0.147	0	0	0	0	0	0
Effective contacts duration	500	0	0	0	0	0	0

This table is for the explanation purpose and the inputs that are used for the simulation are not the desired ones since MATLAB 2014 was not able to demonstrate matrix details for a high number of students. Different number of locations are assigned to the student in different timeline for weekdays. If the number is between 1 and 10, it is going to be constant until the end of simulation because these numbers show classes. However, from 11 to 15 are general locations which are assigned to the student randomly every week. Eighth row can be 0 (Susceptible), 1 (Exposed or Infected), 2 (Recovered), or 3 (Vaccinated). Exposed and Infected stages are differentiated in another matrix that is programmed to determine latent period, infected period, and symptomatic and asymptomatic type of infection. Ninth row is between 0 and 1 which indicates the probability of infection transmission. Therefore, 1 means 100% the infection has been occurred which turns row number eight to 1 as well. Tenth row shows how long the individual had effective contacts during the day in minutes.

Table 13: Axis X and Y of secondary matrix related to disease specifications for student #1

Students #	27	39	41	48
Day #	0	1	2	3
Disease Stage	1	2	2	2
Infection Type	0	0	1	2

Table 13 is the secondary matrix for exposed and infected compartments. The first row is showing students' number, the second row can be 0, 1, 2, 3, and 4 which represent the number of day that the individual has entered to the either exposed or infected stage. The third row shows whether the person is in exposed (with value of 1) or infected (with value of 2). The forth row is 0 if the student is in exposed stage or he/she has asymptomatic infection; it can be 1 if the person has symptomatic infection without any absenteeism and it is 2 if he/she has symptomatic infection who does not attend to classes while he is sick.

Contribution in preventive behaviors (vaccination and hand-washing) are not considered in the baseline codes. For other scenarios, the possibility of receiving flu shot is calculated in the beginning of simulation and whoever become vaccinated, have 50% immunity against influenza. The probability of hand-washing is calculated and assigned to each individual in the beginning of semester but the possibility of taking the action is checked by giving a random number between 0 and 1 every day in order to increase the accuracy. If the random number is less than the initial probability assigned to the student, he/she takes the action and reduce the possibility of infection transmission.

6. Results

In this section we indicate the simulation results. In the data section, we have explained how data were collected and analyzed; the results of the analysis have been used as inputs for our simulations. First, we developed a baseline scenario to without any preventive behaviors involvement to validate with previous simulation studies. The peak day, attack rate, and R_0 are compared to previous similar works for validation. Then, we included odds ratios of hand-washing and vaccination contributions driven by control and treatment groups' data which provide us two scenarios.

In order to receive decent results we need sufficient number of iterations which can be estimated by following formula (Wayne L. Winston, 2000):

$$N = [Z * \frac{S}{E}]^2$$

Where:

N = the number of iterations required for simulation

Z = 1.96 for 95% confidence level

S = 2.6 which is estimated standard deviation driven from 20 random numbers between 20 and 30; we have considered the estimation of peak time would be between day 20 to day 30.

E = 1.2% desired margin of error

Based on these numbers N is equal to 18.03; therefore, 20 iterations would bring enough data to rely on.

6.1. Model Validation

The peak times, the attack rates, and R_0 are three criteria to be compared with other similar studies in order to validate our model. For validation, we assumed no preventive behavior intervenes in our simulation. The peak time is defined the period that the most number of infections occur. The simulation was run for 120 days and after 20 iterations the infection peak days were witnessed between day 20 and 25. The attack rate were more than 50% for every simulation run. The average of all infected students (out of 20 iterations) was 3063 out of 4800 individuals and 1201 of them had caught infected since the beginning of the simulation until the peak time. The number of secondary infected caused by the first infectious person (R_0) can be calculated by the rate of effective contacts and the rate of recovered $R_0 = \beta/v$ (Jones, 2007) that was 1.03 in our study by considering the average of new cases equal to rate of effective contacts. Our baseline results correspond to Yang and Karimi et al. which also modeled influenza transmission in a university setting (Yang, Atkinson, & Ettema, 2008; Karimi, Schmitt and Akgunduz, 2015). Yang predicted a peak time between 20 and 25 days while Karimi et al. predicted a peak time between 25 to 30.Both studies showed an attack rate greater than 50%. Our results (figure 4) also reflect influenza's $R_0 > 1$ for which we expect an outbreak (Kermack & McKendrick, 1927).

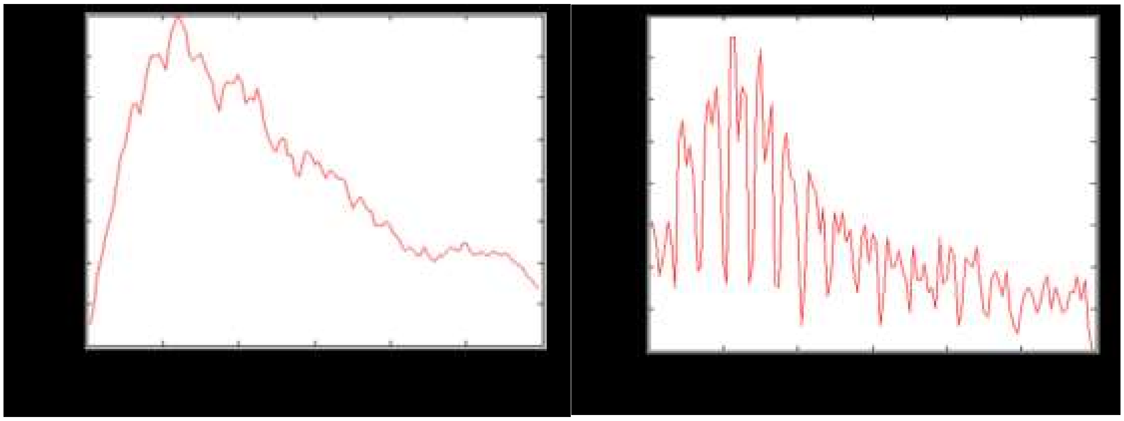

Figure 4: Total (left) and new (right) infections per day for the baseline scenario.

6.2. Effect of Preventive behaviors

The survey results were used to predict the level of preventive behaviors. At first we targeted the control group to simulate vaccination and hand-washing involvements without considering the effect of educational program. The survey explored the impact of an education program on hand-washing behavior using HBM in a university setting. In-class time constraints limited the number of questions we could ask. Since the focus of this survey was hand-washing, we had limited space to have enough questions for both hand-washing and vaccination; therefore, we designed survey focused on hand-washing mostly. However, we considered vaccination in the simulation of the control group because we found correlation between the HBM criteria and this preventive behavior.

Table 14 demonstrates that preventive behaviors decreased total infections by 188 people compared to the baseline while the peak period is shifted forward by several days. Peak number of cases decreases by 15 compared to the baseline scenario. The last row shows the average number of infected individuals within the peak period which decreased for both scenarios. Although the vaccination was not considered for the treatment group the average number of infected people in the peak days dropped 11 times compared to the control scenario.

In table 15The total number of students that practice hand-washing in the control group, based on 20 simulation runs, is 2946 people in average. The simulation run for 119 days and hand-washing occurrence is re-measuring every day for each individual. So, 2946 can be the total number of people that washed their hand during one day. After all it is likely that 43% of them get infected at the end of semester. The number of people who practice hand-washing in the treatment group is 634 times more than control group; however, they influenza is more likely to spread among them since the vaccination is not considered for the treatment group.

The average of 20 simulation runs yielded a total number of vaccinated students of 1796 out of 4800. Of the vaccinated students, 33% contracted influenza.

Figure 5 shows how the influenza infection spreads if preventive behaviors are considered based on data collected from control group.

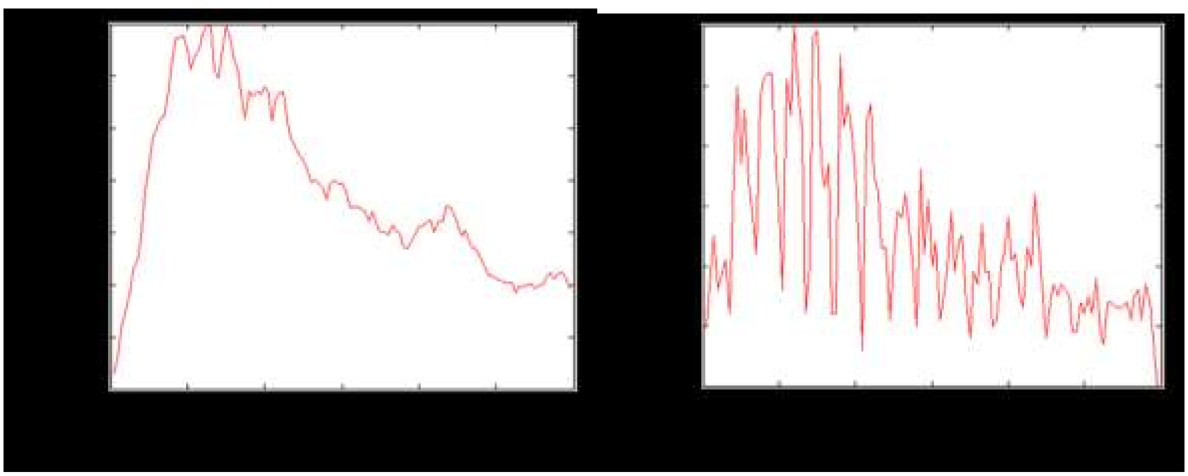

Figure 5: Total (left) and new (right) infections per day for the control scenario.

Table 14: Results of simulation

	Baseline	Control	Treatment
Total infected cases	3064	2876	2691
Peak period	20-25	22-29	22-30
Peak Cases	74	59	50
$\frac{\text{Total Cases within peak period}}{\text{Number of peak days}}$	57	45	34

6.3. Effect of Educational Program

A Concordia Unviersity health specialist delivered the educational program. While the focus of the program was on hand-washing, he covered all aspects of influenza prevention, including social and phsycial distancing and vaccination. The logistic regression analysis indicated that the education program increased the likelihood of hand-washing. In contrast, vaccination was not correlated with the HBM variables, thus it was not considered in this scenario. Table 14 shows that the educational program reduced the total number of infected students by 373 from the baseline. The peak period did not have a significant change from the control group; however, the number of cases that got infected during the peak period decreased to 50 individuals in average. The total number of students that practiced hand-washing is 3580 during a day and 53% of them are likely to catch influenza at the simulation. Table 15 represents the difference of hand-washing behavior between the two groups. Figure 6 demonstrates how the outbreak slowed down by educational program.

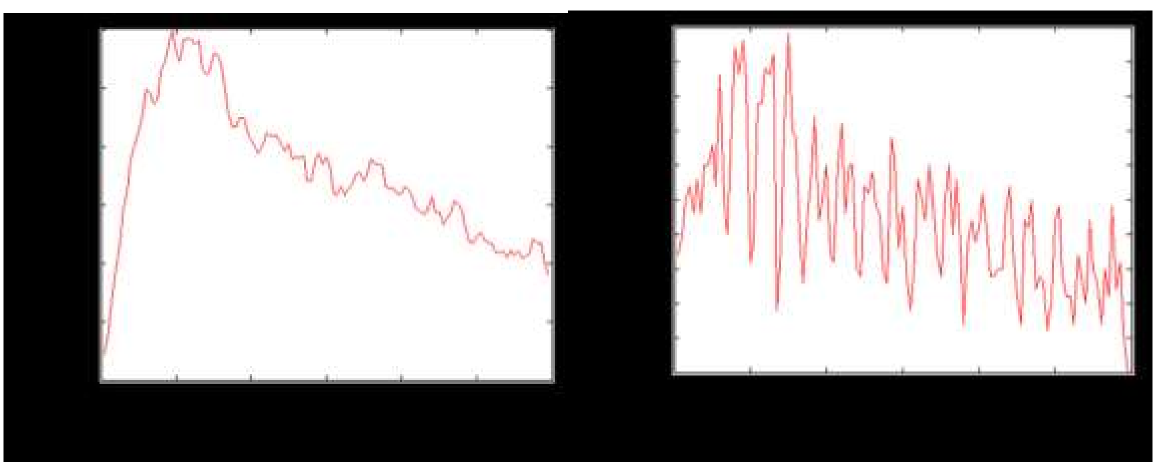

Figure 6: Total (left) and new (right) infections per day for the treatment scenario.

Table15: Hand-washing comparison between control and treatment groups

Total hand-washing cases (control)	2946
Total percentage of infected from hand-washing cases (control)	43%
Total hand-washing cases (treatment)	3580
Total percentage of infected from hand-washing cases (treatment)	53%

7. Conclusion

In this study there are two notable highlights including the results of survey analysis and the simulation results. The survey results can be divided into three parts; evaluation of students' perception about influenza and prevention behaviors, the effect of health educational program, and evaluation of on campus hand-washing and health facilities. Students' perceptions were questioned based on HBM and by a binary logistic regression we could assess the likelihood of practicing the preventive behaviors. As an example, the OR = 2.13 with p-value less than 0.05 confirms that hand-washing is highly correlated with one of HBM criteria named perceived benefit of hand-washing in control group. Not only the mean and the standard deviation, but also the t-test with p-value < 0.05 (for all HBM criteria except perceived barrier) showed a significant difference between control group and treatment group. The results of survey suggest improving the quality of hand-washing facilities and bathrooms such as placing towel papers and high power hand-dryer are necessary and it can bring students' satisfaction.

Nevertheless, it is not wise to conclude based on the results of 242 valid questionnaires. Consequently, a simulation based on 4800 students' interaction in a specified school enables us to determine the influence of preventive behaviors on influenza spread within the seasonal period. By adding the logistic regression formula to the baseline simulation codes we could put the probability of hand-washing and vaccination interventions together to check if influenza transmission rate changes. Based on the ABM results we conclude that it is worth it to increase hand-washing to prevent influenza and in order to do so the treatment (educational program) is a simple and significant solution because it can reduce the attack rate at least 7.7%.

8. Future Work

One of the advantage of this study is that we developed a flexible model which enables us to simulate influenza transmission in different building sizes since the number of people, rooms and general locations are asked; moreover, any age group can be considered because the infection rate (λ) is asked as an input before simulation starts. The simulation model also enables us to either consider vaccination or not; although, the survey was biased in terms of equivalency between hand-washing and vaccination. The main focus was on hand-washing in survey and health educational program. Therefore, this model can provide a better sense of difference between vaccination and hand-washing if a similar survey will be conducted for influenza vaccination.

Another potential study that can be done in future is to gather information about the cost of educational program for the entire society and compare it to the costs of catching influenza for the number of individuals that can be saved by this program. Infection costs include, the treatment and medicine cost, the lower work efficiency, and the absenteeism from work and school. However, in such study a survey for a larger group of cases with different age, race, gender, and background is required.

9. Resources

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Appendix I: Logistic Regression Equation

The Logistic Regression estimates the probability of an event occurring depending on the values of independent variables. The dependent variables in our study are hand-washing and vaccination, and the independent variables are students' perceptions categorized based on HBM.

Our depended variable is binary since it can be either happening or not; therefore, logistic regression is an appropriate approach to find the relationship between protective behaviors and HBM. The credit score of independent variables are 5 units from 1 to 5 and the value of dependent variables can be 0 or 1.

Credit Scores (Independent variables)	Action approved (dependent variables)
1,2,3,4,or 5	0 or 1

The Logistic Regression equation is based on Odds:

$$Odds = \frac{P\ (occurring)}{1-P\ (occurring)}$$

Odds is the possibility of occurrence a behavior over the possibility of not occurring the behavior. Whereas, Odds Ratio (OR) is the Odds of a behavior with condition 1 over the Odds with condition 0 for the same behavior. The condition 0 represents constant independent variables while in the condition 1, one of the independent variables is increased one unit.

	Hand-washing
Perceived susceptibility	2.03

The Odds ratio indicates the influence of independent variables on dependent variables. The above table shows the odds ratio = 2.03 between perceived susceptibility and hand-washing which can be interpreted like this: If someone's perception about susceptibility increases for one unit, this person is 2.03 more likely to wash his/her hands.

Logit is the natural log of odds:

$logit\ (p) = \ln(\frac{p}{1-p})$

Estimated regression equation (probability of occurring):

$$P = \ logit^{-1}(\alpha) = \ \frac{e^{\alpha}}{1 + \ e^{\alpha}}$$

The alpha (α) is a linear combination of independent variables and their coefficients:

$\alpha = \ \beta_0 + \beta_1 X_1$

Where:

$\beta_0: constant\ coeficiant$

$\beta_1: FicoScore\ coeficiant$

$X_1: the\ credit\ scores\ of\ the\ independent\ variables\ given\ by\ students$

We summarized the credit scores to 1, 3 and 5 for the sake of simplicity. The value 2 is considered 1 and the value 4 considered 5.

In order to have 95% certainty that the data has the true mean of the population covered, we considered 95% of Confidence Interval (CI) for all analysis stages.

Appendix II: Essential Codes

These codes are essential parts of the control simulation since the control includes both preventive behaviors. Some short explanations of each section can be found between two percentage signs.

```
%Determining different number of days for people in the exposed stage to stay
in this compartment%

No_Student_Sick=[No_Student_Sick   ;   ones(1,Num_Sick);   ones(1,Num_Sick)   ;
zeros(1,Num_Sick)];
No_Student_Sick(3,p_E+1:Num_Sick)=2;

E_1D=round(0.3*p_E);
E_2D=round(0.5*p_E);
E_3D=round(0.2*p_E);
No_Student_Sick(2,          1:E_1D)=1;
No_Student_Sick(2,E_1D+1:E_1D+E_2D)=2;
No_Student_Sick(2, E_1D+E_2D+1:p_E)=3;

%Determining different number of days for people in the infected stage to stay
in this compartment%

p_I=Num_Sick-p_E;
I_3D=floor(0.3*p_I);
I_4D=floor(0.4*p_I);
I_5D=floor(0.2*p_I);
I_6D=p_I-I_3D-I_4D-I_5D;

if ((p_E+ I_3D)-(p_E+1))>=0
    No_Student_Sick(2,       p_E+1                            :    p_E+ I_3D
)=3;
end

if (p_E+ I_3D +I_4D)-(p_E+I_3D +1)>=0
    No_Student_Sick(2,      p_E+I_3D +1                 :    p_E+ I_3D +I_4D
)=4;
end

if ( p_E+ I_3D +I_4D+I_5D )-(p_E+ I_3D +I_4D +1)>=0
    No_Student_Sick(2,     p_E+ I_3D +I_4D +1        :   p_E+ I_3D +I_4D+I_5D
)=5;
end

if ( p_E+ I_3D +I_4D+I_5D+I_6D )-(p_E+ I_3D +I_4D +I_5D +1)>=0
    No_Student_Sick(2,         p_E+  I_3D  +I_4D  +I_5D  +1     :     p_E+  I_3D
+I_4D+I_5D+I_6D)=6;
end


count_I=0;
count_E=0;
```

```
for i=1:length(No_Student_Sick)
    if No_Student_Sick(3,i)==2
        count_I=count_I+1;
    else
        count_E=count_E+1;
    end
end


%Determining if the infection is asymptomatic or symptomatic%


Ass_num=round(count_I*0.33);
Sym_num=count_I-Ass_num;
Sym_abs=round(Sym_num*0.33);

for i=count_E+Ass_num+1  :  length(No_Student_Sick)
    if Sym_abs ~=0
       No_Student_Sick(4,i)=1;
       Sym_abs=Sym_abs-1;
    else
       No_Student_Sick(4,i)=2;
    end
end

%Defining the main matrix%

Students3=zeros(10,7*17,Num_Students);
Max_Day_Sick=4;
Prob=rand(1);
Recovered=[];
Num_Days_Term=17*7;

%Determining  the  probability  of  vaccination  based  on  logistic  regression
equation%

Count_Vax=0;
for iv=1:Num_Students

            x1=rand(1);
            if x1< 0.33
                x1=1;
            elseif x1<75
                x1=3;
            else
                x1=5;
            end
            beta0 = -1.6515;
            beta1 = 0.3670;
            P3_vax=exp(beta0+(beta1*x1))/  (1+exp(beta0+(beta1*x1)));

            x1=rand(1);
            if x1< 0.37
                x1=1;
            elseif x1<66
```

```
            x1=3;
        else
            x1=5;
        end
        beta0 = 0.9837;
        beta1 = -0.5712;
        P4_vax=exp(beta0+(beta1*x1))/  (1+exp(beta0+(beta1*x1)));

        P=(P3_vax+P4_vax)/2;
        pr=rand(1);

%Determining the probability of hand-washing based on logistic regression equation%

        x1=rand(1);
        if x1<0.04
            x1=1;
        elseif x1<0.08
            x1=3;
        else
            x1=5;
        end
        beta0 = -1.8448;
        beta1 =  0.7602;
        P3_hand=exp(beta0+(beta1*x1))/  (1+exp(beta0+(beta1*x1)));


        x1=rand(1);
        if x1<0.5
            x1=1;
        elseif x1<0.77
            x1=3;
        else
            x1=5;
        end
        beta0 = 3.4992;
        beta1 = -0.6972;
        P4_hand=exp(beta0+(beta1*x1))/  (1+exp(beta0+(beta1*x1)));

        P=(P3_hand+P4_hand)/2;

%Turning from Exposed to Infected%

if(No_Student_Sick(3,j)== 1   &&  No_Student_Sick(2,j)==0 )
  No_Student_Sick(3,j)=2;
  Students(8,i,No_Student_Sick(1,j))=1;
  Students(9,i,No_Student_Sick(1,j))=1;

  %Determine number of sick days%
  rp=rand();
  if rp<=0.1
      No_Student_Sick(2,j)=6;
  elseif rp>0.1 && rp<=0.3
      No_Student_Sick(2,j)=5;
  elseif rp>0.3 && rp<=0.7
```

```
        No_Student_Sick(2,j)=4;
    elseif rp>0.7 && rp<=1
        No_Student_Sick(2,j)=3;
    end

    %Determine Symptomatic or Asymptomatic%
    rp=rand();
    if rp>0.33
         No_Student_Sick(4,j)=2;
         rrp=rand();
         if rrp<0.33
         No_Student_Sick(4,j)= 1;
         else
         No_Student_Sick(4,j)= 2;
         end
    else
      No_Student_Sick(4,j)=0;
    end

  elseif (No_Student_Sick(3,j)== 1   &&  No_Student_Sick(2,j)==1 )
    Students(8,i,No_Student_Sick(1,j))=1;
    Students(9,i,No_Student_Sick(1,j))=1;
    No_Student_Sick(2,j)= No_Student_Sick(2,j)-1;

  elseif (No_Student_Sick(3,j)== 1   &&  No_Student_Sick(2,j)==2 )
    Students(8,i,No_Student_Sick(1,j))=1;
    Students(9,i,No_Student_Sick(1,j))=1;
    No_Student_Sick(2,j)= No_Student_Sick(2,j)-1;

  elseif (No_Student_Sick(3,j)== 1   &&  No_Student_Sick(2,j)==3 )
    Students(8,i,No_Student_Sick(1,j))=1;
    Students(9,i,No_Student_Sick(1,j))=1;
    No_Student_Sick(2,j)= No_Student_Sick(2,j)-1;

  %Turning from Infected to Recovered%

  elseif (No_Student_Sick(3,j)== 2   &&  No_Student_Sick(2,j)==0 )

    Recovered=[Recovered    No_Student_Sick(1,j)];
    Students(8,i,No_Student_Sick(1,j))=2;
    Students(9,i,No_Student_Sick(1,j))=0;

    if i<Num_Days_Term
        Students(8,i+1,No_Student_Sick(1,j))=2;
        Students(9,i+1,No_Student_Sick(1,j))=0;
    end

    No_Student_Sick(:,j)=[];
    j=j-1;
    Num_Sick=Num_Sick-1;


  %Condition: infected, symptomatic and absent%
```

```
elseif   (No_Student_Sick(3,j)==   2         &&      No_Student_Sick(2,j)~=0   &&
        No_Student_Sick(4,j)==1 )
  Students(8,i,No_Student_Sick(1,j))=1;
  Students(9,i,No_Student_Sick(1,j))=1;
  No_Student_Sick(2,j)= No_Student_Sick(2,j)-1;

%Condition: infected, asymptomatic%

elseif   (No_Student_Sick(3,j)==   2         &&      No_Student_Sick(2,j)~=0   &&
        No_Student_Sick(4,j)==0 )
  Students(8,i,No_Student_Sick(1,j))=1;
  Students(9,i,No_Student_Sick(1,j))=1;
  No_Student_Sick(2,j)= No_Student_Sick(2,j)-1;

  rp=rand();
  if rp>0.5
    for                                                                    k=1:7
             for                                                  m=1:Num_Students
              if         Students(8,i,m)==2         &&          i<Num_Days_Term
                 Students(9,i,m)=0;
                 Students(8,i+1,m)=2;
              end

              if                      Students(8,i,m)==0                        &&
                 Students(k,i,No_Student_Sick(1,j))==Students(k,i,m)            &&
                 m~=No_Student_Sick(1,j)  && Students(k,i,m)~=0

                   p=rand(1);

                   %Near      susceptible      students      in      classes%

                   if p > 0.8

                     if  Students(k,i,m)<= All_Classes

                       %P-state    represents    the    hand-washing    action%

                       if P_state==0

                           Students3(k ,i,m)=Students3(k ,i,m)+120;

                           Students(10,i,m)=Students(10,i,m)+120;

                       end


                       if P_state==1

                           Students3(k ,i,m)=Students3(k ,i,m)+120*0.79;

                           Students(10,i,m)=Students(10,i,m) +120*0.79;

                       end
```

```
      %Near      susceptible      students      in      classes%
      else
        if P_state==0
            Students3(k ,i,m)=20;
            Students(10,i,m)=Students(10,i,m)+20;
        end

        if P_state==1
            Students3(k ,i,m)=20*0.79;
            Students(10,i,m)=Students(10,i,m)+20*0.79;
        end

      end
    end
end

%Vaccinated         and         susceptible         students%
if                      Students(8,i,m)==3                     &&
   Students(k,i,No_Student_Sick(1,j))==Students(k,i,m)     &&
   m~=No_Student_Sick(1,j)  && Students(k,i,m)~=0

   p=rand(1);
   if p > 0.8
       if  Students(k,i,m)<= All_Classes
           Students3(k ,i,m)=Students3(k ,i,m)+120/2;
           Students(10,i,m)=Students(10,i,m)+120/2;
       else
           Students3(k ,i,m)=20/2;
           Students(10,i,m)=Students(10,i,m)+20/2;
       end
   end
```

```
                end
             end
          end
       end

%Condition:                    infected,                    symptomatic%

elseif     No_Student_Sick(3,j)==   2     &&     No_Student_Sick(2,j)~=0   &&
        No_Student_Sick(4,j)== 2
        Students(8,i,No_Student_Sick(1,j))=1;
        Students(9,i,No_Student_Sick(1,j))=1;
        No_Student_Sick(2,j)= No_Student_Sick(2,j)-1;

      for k=1:7
         for m=1:Num_Students

            if Students(8,i,m)==2 && i<Num_Days_Term
               Students(9,i,m)=0;
               Students(8,i+1,m)=2;
            end

            if                      Students(8,i,m)==0                      &&
               Students(k,i,No_Student_Sick(1,j))==Students(k,i,m)          &&
               m~=No_Student_Sick(1,j) && Students(k,i,m)~=0

               p=rand(1);
               if p > 0.8

                  if  Students(k,i,m)<= All_Classes

                      if P_state==0

                          Students3(k ,i,m)=Students3(k ,i,m)+120;

                          Students(10,i,m)=Students(10,i,m)+120;

                      end


                      if P_state==1

                          Students3(k ,i,m)=Students3(k ,i,m)+120*0.79;

                          Students(10,i,m)=Students(10,i,m) +120*0.79;

                      end

                  else

                      if P_state==0

                          Students3(k ,i,m)=20;

                          Students(10,i,m)=Students(10,i,m)+20;
```

```
                    end


                    if P_state==1

                        Students3(k ,i,m)=20*0.79;

                        Students(10,i,m)=Students(10,i,m)+20*0.79;

                    end

                end
            end
         end
       end
    end

end
```

Appendix III: Survey

Gender

☐ Female ☐ Male ☐ Prefer to self-describe__________

Age

☐ 15 to 19 ☐ 20 to 24 ☐ 25 to 29 ☐ 30 or more

Please select the best option:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. I feel knowledgeable about the risk of getting the influenza virus.	☐	☐	☐	☐	☐
2. When I am exposed to the influenza virus, I will get sick.	☐	☐	☐	☐	☐
3. When I am exposed to the flu virus, others in my facility will get sick.	☐	☐	☐	☐	☐
4. Avoiding physical contact with sick people reduces my likelihood of catching the flu.	☐	☐	☐	☐	☐
5. It is convenient to get the influenza vaccine.	☐	☐	☐	☐	☐
6. When I have not been vaccinated against influenza, I wash my hands more often.	☐	☐	☐	☐	☐
7. It is inconvenient to wash hands on campus.	☐	☐	☐	☐	☐
8. Soap on campus dries my skin	☐	☐	☐	☐	☐
9. There is enough hand sanitizer on campus.	☐	☐	☐	☐	☐
10. There is enough soap in the bathrooms on-campus.	☐	☐	☐	☐	☐
11. There are enough paper-towels in the bathrooms on-campus.	☐	☐	☐	☐	☐
12. There are enough hand dryers in the bathrooms on-campus.	☐	☐	☐	☐	☐
13. Hand dryers on-campus do a good job drying hands.	☐	☐	☐	☐	☐

	Never	Rarely	Sometimes	Often	Always
14. When I shake someone's hand who is sick, I wash my hands.	☐	☐	☐	☐	☐
15. When I have the flu, I am not able to study.	☐	☐	☐	☐	☐
16. When I have the flu, I cannot attend my classes.	☐	☐	☐	☐	☐
17. When I have the flu during exams, I fail them.	☐	☐	☐	☐	☐
18. When I wash my hands more often, I will not get the flu.	☐	☐	☐	☐	☐
19. When I go to an on-campus bathroom to urinate (pee), I wash my hands.	☐	☐	☐	☐	☐
20. When I go to an on-campus bathroom to defecate (poop), I wash my hands.	☐	☐	☐	☐	☐
21. When I touch an elevator button, a doorknob or a hand rail, I wash my hands.	☐	☐	☐	☐	☐
22. Before having food, I wash my hands.	☐	☐	☐	☐	☐
23. When the sink is dirty, I don't wash my hands.	☐	☐	☐	☐	☐
24. When there is no soap, I don't wash my hands.	☐	☐	☐	☐	☐
25. When there are no paper-towels, I don't wash my hands.	☐	☐	☐	☐	☐
26. When there is no hand dryer or the hand dryer is broken, I don't wash my hands.	☐	☐	☐	☐	☐

27. How often do the following resources provide you with information about flu?

	Never	Sometimes	Often	Very Often
TV	☐	☐	☐	☐
Newspaper	☐	☐	☐	☐
Family member or friend	☐	☐	☐	☐
Pharmacist	☐	☐	☐	☐
Nurse	☐	☐	☐	☐
University posters and brochures	☐	☐	☐	☐
Internet	☐	☐	☐	☐
Other (Please specify):	☐	☐	☐	☐

28. How likely are you to use the following to prevent flu?

	Never	Sometimes	Often	Very Often
Vaccine	☐	☐	☐	☐
Avoiding physical contact	☐	☐	☐	☐
Using masks	☐	☐	☐	☐
Washing hands	☐	☐	☐	☐
Using hand sanitizer	☐	☐	☐	☐
Avoid coming into contact with germs	☐	☐	☐	☐
Cover your mouth when you cough	☐	☐	☐	☐
Avoid touching your face (nose, eyes and mouth)	☐	☐	☐	☐
Antiviral drugs	☐	☐	☐	☐
Other (Please specify):	☐	☐	☐	☐

29. Have you been vaccinated against the flu this year?

☐ No ☐ Yes