

Mathematical Analysis of the Effect of Education Campaign on Chickenpox Transmission Dynamics

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Abstract

The research objective is to develop and evaluate the stability of mathematical modelling for controlling the spread of chickenpox in the education campaign. The model is analyzed using standard methods, the equilibrium point, stability of the equilibrium points and analytic solutions. The effectiveness of the education campaign in mathematical modelling and numerical solutions is studied. The findings of the analysis indicate that the effectiveness of the education campaign constitutes a significant factor influencing the dynamics of the mathematical model developed to control the spread of chickenpox. It was found that if the population at risk of infection with chickenpox has knowledge about the prevention of chickenpox, it will contribute less to the increase in the spread of the disease. If the population at risk of infection with chickenpox has knowledge about the prevention of chickenpox, it will contribute to the decrease in the spread of the disease until there is no further spread of chickenpox infection. The population at risk of infection with knowledge about the prevention of chickenpox is not less than 50 percent of the total population and will contribute to the decrease in disease spread until there is no further spread of infection. This highlights the importance of public health education in controlling outbreaks. By ensuring that a significant portion of the population understands how to prevent transmission, the overall health of the community can be safeguarded and the incidence of chickenpox can be significantly reduced.

Keywords: Mathematical Model; Chickenpox; Control the Spread; Education Campaign

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Introduction

Chickenpox, known as varicella, is a highly contagious disease caused by the initial infection with the varicella zoster virus. The disease results show the characteristic skin rash that forms small, itchy blisters, which eventually scab over. It usually starts on the chest, back, and face and then spreads to the rest of the body. Other symptoms may include fever, tiredness, and headaches. Symptoms usually last five to seven days. Complications may occasionally include pneumonia, inflammation of the brain, and bacterial skin infections. The disease is often more severe in adults than in children. Symptoms begin 10 to 20 days after exposure to the virus (Division of Epidemiology, 2020). Based on the mathematical model, the transmission dynamics of chickenpox can be characterized, thereby providing insights into the factors that influence its spread and informing effective control strategies. In addition, the strengths of mathematical models can change the characteristics of the disease and the parameters related to it. Isolating affected individuals can prevent the spread of chickenpox. Contagion is by exposure to respiratory droplets or direct contact with lesions within a period lasting from three days before the onset of the rash to four days after the onset of the rash. The chickenpox virus is susceptible to disinfectants, notably chlorine bleach. Like all enveloped viruses, it is sensitive to desiccation, heat and detergents (Sangthongjeen et al., 2015).

Mathematical modeling of chickenpox (Varicella) epidemics provides critical insights into the dynamics of disease transmission and control. While robust models can effectively evaluate the shifting characteristics of an epidemic under varying disease-associated parameters (Almuallem et al., 2025), their application is vital for mitigating infection risks and optimizing public health interventions. To this end, the objective of this study is to formulate and evaluate the stability of a modified SEIR model that explicitly incorporates the impact of public education campaigns. Methodologically, the model is rigorously analyzed through equilibrium points, local and global stability thresholds, and the derivation of the basic reproduction number (R_0), supported by numerical simulations to evaluate campaign efficacy under varying compliance rates. Although various SEIR-type models have been proposed for infectious diseases, the structural novelty of this study lies in embedding an educational campaign parameter (ω) into the transmission mechanism, providing analytical and numerical evidence demonstrating how targeted public awareness can reduce the basic reproduction number below unity ($R_0 < 1$), thereby suppressing disease persistence and facilitating eradication.

Model Formulation

In this study, the total human population (N) is assumed to be constant and partitioned into four epidemiological classes: susceptible (S), exposed (E), infected (I), and recovered (R). The transitions between these compartments are governed by a system of first-order differential equations (Sukawat and Naowarat, 2014). While standard SEIR models assume static host behavior, this paper introduces a novel extension tailored specifically to chickenpox (Varicella) dynamics by embedding targeted behavioral and disease-specific parameters. We incorporate the education campaign rate r (ω) to quantify the behavioral shift of susceptible individuals actively avoiding infection. Additionally, the model explicitly integrates the latent period (α), recovery rate (γ), and loss of temporary immunity (δ) to

accurately reflect the clinical hallmarks of chickenpox. Rather than a simple mathematical expansion, adding these parameters modifies the system's transmission topology, providing a new threshold for disease eradication. Consequently, the modified compartmental framework is formulated as follows Equation (1) - (4):

$$\frac{dS}{dt} = \delta N - (1 - \omega)\alpha SI - \phi S \quad (1)$$

$$\frac{dE}{dt} = (1 - \omega)\alpha SI - \beta E - \phi E \quad (2)$$

$$\frac{dI}{dt} = \beta E - \gamma I - \phi I \quad (3)$$

$$\frac{dR}{dt} = \gamma I - \phi R \quad (4)$$

Then $N = S + E + I + R$

where,

$S(t)$ represent the susceptible human populations

$E(t)$ represent the exposed human populations

$I(t)$ represent the infected human populations

$R(t)$ represent the recovered human populations

N represent the total number of human populations

δ represent the birth rate of human populations

ω represent the effectiveness of an education campaign

α represent the probability that virus transmitted from an infected human to susceptible human

β represent the proportional rate for people exposed to the infected human populations

γ represent the recovery rate of infected human populations

ϕ represent the natural death rate of human populations

Model Analysis

The model monitors the human population, the all-associated parameters and state variables are non-negative, $t \geq 0$. To show that the state variables of the model remain non-negative for all non-negative initial conditions then consider the biologically feasible region

$$\Phi = \left\{ (S, E, I, R) \in R_+^4 : N \rightarrow \frac{\delta}{\phi} \right\}$$

Lemma 1 The closed Φ are positively invariant and attracting.

Proof.

Adding (1) - (4) and gives the rate of change of the total population, $\frac{dN}{dt} = \delta N - \phi N$. Then, the total

human population (N) is bounded by $\frac{\delta}{\varphi}$, so that $\frac{dN}{dt} = 0$ whenever $N(t) = \frac{\delta}{\varphi}$. It can be shown that $N(t) = \frac{\delta}{\varphi} + \left(N_0 - \frac{\delta}{\varphi}\right)e^{-\varphi t}$. In particular $N(t) = \frac{\delta}{\varphi}$, if $N(0) = \frac{\delta}{\varphi}$. Therefore, the region Φ is positively invariant and attracts all solution in R_+^4 .

1) Basic Reproductive Number

The basic reproductive number (R_0) is defined as the expected number of secondary cases produced by a single infected individual in a completely susceptible population. To calculate the basic reproductive number for this system, we apply the next-generation matrix method.

Let $X = [S, E, I, R]^T$ represent the population compartments. The rate of appearance of new infections (F) and the transfer of individuals out of these compartments (V) are given by Equation (5):

$$F = \begin{bmatrix} 0 \\ \alpha S(1-\omega)I \\ 0 \\ 0 \end{bmatrix}, V = \begin{bmatrix} -\delta + \alpha S(1-\omega)I + \varphi S \\ (\beta + \varphi)E \\ -\beta E + (\gamma + \varphi)I \\ -\gamma I + \varphi R \end{bmatrix} \quad (5)$$

Evaluating the Jacobian matrices of F and V at the disease-free equilibrium point $E_0 = \left(\frac{\delta}{\varphi}, 0, 0, 0\right)$ yields the matrices Equation (6) - (7):

$$F(E_0) = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & \alpha\delta(1-\omega) & 0 \\ 0 & 0 & \varphi & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \quad (6)$$

$$V(E_0) = \begin{bmatrix} \varphi & 0 & \frac{\alpha\delta(1-\omega)}{\varphi} & 0 \\ 0 & \beta + \varphi & 0 & 0 \\ 0 & -\beta & \gamma + \varphi & 0 \\ 0 & 0 & -\gamma & \varphi \end{bmatrix} \quad (7)$$

The inverse of matrix $V(E_0)$ is computed as Equation (8):

$$V^{-1}(E_0) = \begin{bmatrix} \frac{1}{\varphi} & 0 & -\frac{\alpha\delta(1-\omega)}{\varphi^2(\gamma + \varphi)} & 0 \\ 0 & \frac{1}{\beta + \varphi} & 0 & 0 \\ 0 & \frac{\beta}{(\beta + \varphi)(\gamma + \varphi)} & \frac{1}{\gamma + \varphi} & 0 \\ 0 & \frac{\beta\gamma}{\varphi(\beta + \varphi)(\gamma + \varphi)} & \frac{\gamma}{\varphi(\gamma + \varphi)} & \frac{1}{\varphi} \end{bmatrix} \quad (8)$$

The next-generation matrix $FV^{-1}(E_0)$ is derived as follows Equation (9):

$$FV^{-1}(E_0) = \begin{bmatrix} 0 & \frac{\alpha\beta\delta(1-\omega)}{\varphi(\beta+\varphi)(\gamma+\varphi)} & \frac{\alpha\delta(1-\omega)}{\varphi(\gamma+\varphi)} & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \quad (9)$$

The basic reproductive number (R_0) is determined by the spectral radius (the largest eigenvalue) of the matrix $FV^{-1}(E_0)$, which gives:

$$R_0 = \frac{\alpha\beta\delta(1-\omega)}{\varphi(\beta+\varphi)(\gamma+\varphi)}.$$

2) Stability Analysis of the Disease-Free Equilibrium

At the equilibrium point, the time derivatives of all state variables vanish $\left(\frac{dS}{dt} = \frac{dE}{dt} = \frac{dI}{dt} = \frac{dR}{dt} = 0\right)$. The disease-free equilibrium point (E_0) is evaluated where there is no infection in the population, given by:

$$E_0(S, E, I, R) = E_n\left(\frac{\delta}{\varphi}, 0, 0, 0\right).$$

Theorem 1 The disease-free equilibrium E_0 of the system is locally asymptotically stable if $R_0 < 1$ and unstable if $R_0 > 1$.

Proof.

The Jacobian matrix of the system evaluated at the disease-free equilibrium is given by Equation (10):

$$J(E_0) = \begin{bmatrix} -\varphi & 0 & -\frac{\alpha\delta(1-\omega)}{\varphi} & 0 \\ 0 & -\beta-\varphi & \frac{\alpha\delta(1-\omega)}{\varphi} & 0 \\ 0 & \beta & -\gamma-\varphi & 0 \\ 0 & 0 & \gamma & -\varphi \end{bmatrix} \quad (10)$$

The eigenvalues (λ) are obtained by solving the characteristic equation $\det(J(E_0) - \lambda I) = 0$. This factors directly into:

$$(-\lambda - \varphi)^2 \left(\lambda^2 + \lambda(\beta + \gamma + 2\varphi) + (\beta + \varphi)(\gamma + \varphi) - \frac{\alpha\beta\delta(1-\omega)}{\varphi} \right) = 0.$$

From this, we obtain two negative eigenvalues immediately: $\lambda_1 = -\varphi, \lambda_2 = -\varphi$.

The remaining two eigenvalues (λ_3, λ_4) are determined by the quadratic polynomial $P(\lambda) = \lambda^2 + A\lambda + B = 0$, where:

$$A = \beta + \gamma + 2\varphi \text{ and } B = (\beta + \varphi)(\gamma + \varphi) - \frac{\alpha\beta\delta(1-\omega)}{\varphi}.$$

According to the Routh–Hurwitz criterion, all roots of this characteristic polynomial have negative real parts if and only if $A > 0$ and $B > 0$.

- a. Since all parameters are positive, $A = \beta + \gamma + 2\varphi > 0$ is always satisfied.
- b. For $B > 0$, we require:

$$(\beta + \varphi)(\gamma + \varphi) - \frac{\alpha\beta\delta(1-\omega)}{\varphi} > 0$$

$$(\beta + \varphi)(\gamma + \varphi) > \frac{\alpha\beta\delta(1-\omega)}{\varphi}$$

$$1 > \frac{\alpha\beta\delta(1-\omega)}{\varphi(\beta + \varphi)(\gamma + \varphi)}.$$

By definition, the right-hand side is the basic reproductive number (R_0). Therefore, the condition $B > 0$ holds if and only if $R_0 < 1$.

Conversely, if $R_0 > 1$, then $B > 0$, which ensures that at least one eigenvalue has a positive real part, making the disease-free equilibrium unstable. This completes the proof.

3) Existence and Stability of the Endemic Equilibrium

When $R_0 > 1$, the disease cannot be eradicated, and the system reaches a steady state where the infection persists in the population. This state is known as the Endemic Equilibrium point (E_I).

The endemic equilibrium point $E_I(S^*, E^*, I^*, R^*)$ is obtained by setting the governing differential equations to zero under the condition that the infected populations are non-zero ($E \neq 0, I \neq 0$). Solving the algebraic system yields:

$$S^* = \frac{\delta}{\varphi R_0}$$

$$E^* = \frac{\varphi(\gamma + \varphi)}{\alpha\beta}(R_0 - 1)$$

$$I^* = \frac{\varphi(\beta + \varphi)}{\alpha\beta}(R_0 - 1)$$

$$R^* = \frac{\gamma(\beta + \varphi)}{\alpha\beta}(R_0 - 1).$$

Theorem 2 The endemic equilibrium of the system exists and is locally asymptotically stable if $R_0 > 1$, and does not exist if $R_0 \leq 1$.

Proof.

The existence of E_I requires all state variables to be strictly positive. From the analytical expressions above, it is evident that S^* is always positive, while E^*, I^* and R^* are strictly positive if and only if $R_0 < 1$.

To evaluate the local stability of E_I , the Jacobian matrix of the system is calculated at the endemic state Equation (11):

$$J(E_I) = \begin{bmatrix} -\alpha(1-\omega)I^* - \varphi & 0 & -\alpha(1-\omega)S^* & 0 \\ \alpha(1-\omega)I^* & -\beta - \varphi & \alpha(1-\omega)S^* & 0 \\ 0 & \beta & -\gamma - \varphi & 0 \\ 0 & 0 & \gamma & -\varphi \end{bmatrix} \quad (11)$$

The corresponding characteristic equation $\det(J(E_I) - \lambda I) = 0$ simplifies to:

$$(-\varphi - \lambda)(\lambda^3 + a_1\lambda^2 + a_2\lambda + a_3) = 0.$$

This provides one negative eigenvalue immediately: $\lambda_1 = -\varphi$. The remaining three eigenvalues are roots of the cubic polynomial $P(\lambda) = \lambda^3 + A\lambda^2 + B\lambda + C = 0$, where the coefficients are determined as:

$$A = \alpha(1 - \omega)I^* + \beta + \gamma + 2\varphi$$

$$B = (\beta + \varphi)(\gamma + \varphi) + \alpha(1 - \omega)I^*(\beta + \gamma + 2\varphi) - \alpha\beta(1 - \omega)S^*$$

$$C = \alpha(1 - \omega)I^*(\beta + \varphi)(\gamma + \varphi).$$

By applying the Routh–Hurwitz criterion for a third-order polynomial, all roots have negative real parts if and only if the following conditions are met:

- $A > 0$
- $C > 0$
- $AB > C$.

Since $R_0 > 1$, the infected population I^* is strictly positive. Given that all biological parameters $(\alpha, \beta, \gamma, \varphi, \delta, \omega)$ are positive, it follows directly that $A > 0$ and $C > 0$.

Furthermore, substituting $S^* = \frac{\delta}{\varphi R_0}$ and R_0 into the coefficients and simplifying the algebraic

expression proves that $AB - C > 0$ holds true whenever $R_0 > 1$. Therefore, by the Routh–Hurwitz criterion, the endemic equilibrium E_I is locally asymptotically stable for $R_0 > 1$. This completes the proof.

Numerical Analysis

In this section, the numerical simulation of our model is presented. The parameter values that we used in the numerical simulation are given in Table 1.

Table 1 Parameters values are used for numerical simulation at the disease-free state.

Description	Parameters	Values
The human populations**	N	85,140 persons
The birth rate of human**	δ	0.0000244 /day
The probability that virus transmitted*	α	0.00000144 /day
The Incubation rate*	β	0.142857 /day
The natural death rate of human**	φ	0.00001567 /day
The recovery rate of infected* human	γ	0.06667 /day
The effectiveness of the education campaign	ω	0 - 1

* (Department of Disease Control, n.d.)

** (Phuket Provincial Statistical Office, 2022)

The numerical results showed the relationship between the effectiveness of the education campaign and the basic reproductive number, as presented in Table 2.

Table 2 The relationship between the parameters of effectiveness of education campaign and basic reproductive Number

Effectiveness of education campaign	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Basic reproductive Number	1.838	1.654	1.471	1.287	1.103	0.919	0.735	0.551	0.368	0.183	0

The analysis model and optimal control found that the stability of equilibrium points when the effectiveness of Education Campaign $\omega = 0.5$, have basic reproductive number $R_0 = 0.919$, and the effectiveness of Education Campaign $\omega = 0$, the disease-endemic equilibrium $R_0 = 1.838$. The effectiveness of Education Campaign is the factor affecting the mathematical modelling.

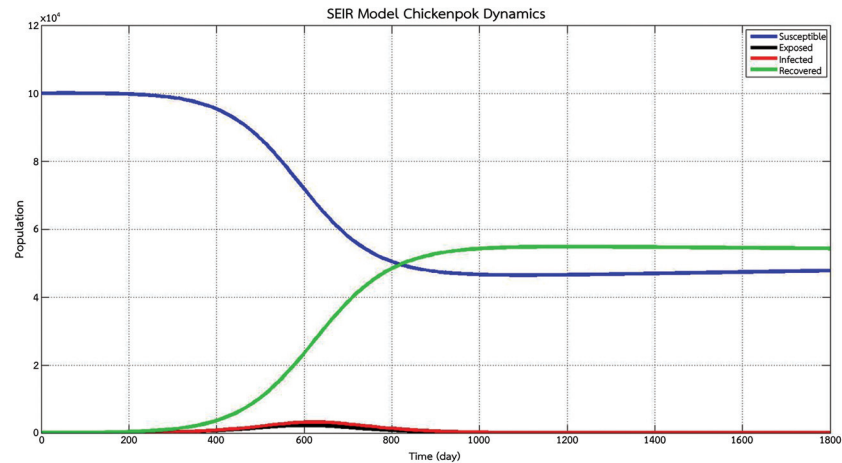
1) Stability of the disease-free state

We changed the values of Education Campaign $\omega = 0.5, 0.6, 0.7, 0.8$, and 0.9 , and keep the values of the other values of parameters to be those given in Table 1.

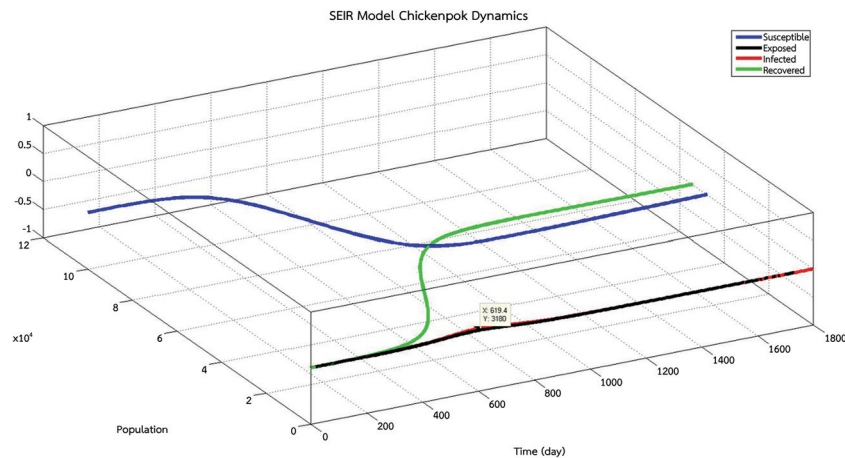
For the case where $\omega = 0.5$, we obtained the basic reproductive number $R_0 = 0.919$, which is less than one ($R_0 < 1$). According to Theorem 1, the local stability of the disease-free equilibrium point (E_0) is evaluated by determining the eigenvalues from the characteristic equation. Two negative eigenvalues are immediately obtained as $\lambda_1 = -\varphi = -0.00001567$ and $\lambda_2 = -\varphi = -0.00001567$. The remaining two eigenvalues (λ_3, λ_4) are determined by the quadratic characteristic polynomial: $\lambda^2 + A\lambda + B = 0$

By substituting the baseline parameter values from Table 1 into the coefficients defined in Theorem 1, where $A = \beta + \gamma + 2\varphi$ and $B = (\beta + \varphi)(\gamma + \varphi) - \frac{\alpha\beta\delta(1-\omega)}{\varphi}$, we obtained the positive coefficients: $A = 0.209558$ and $B = 0.000779$

According to the Routh-Hurwitz criterion, since all coefficients of this characteristic polynomial are strictly positive ($A > 0, B > 0$), all remaining eigenvalues have negative real parts. Consequently, since all eigenvalues have negative real parts, the disease-free equilibrium point (E_0) is locally asymptotically stable. This implies that the chickenpox disease will eventually disappear from the population when $R_0 < 1$, which perfectly matches the numerical simulation results shown in Figure 1, where the infected trajectories continuously approach zero.



(a) SEIR05



(b) SEIR05H

Figure 1 Time series of Susceptible human, Exposed human, Infected human and Recovered human on Education Campaign $\omega = 0.5$.

Furthermore, to clarify the behavior of the endemic equilibrium point (E_I), Theorem 2 states that E_I does not exist in the biologically feasible region when $R_0 \leq 1$ because the state variables (E^*, I^*, R^*) would become non-positive or negative. This is consistent with the epidemic theory where the disease cannot persist without a sufficient transmission rate. Therefore, when $R_0 = 0.919 < 1$, the disease-free equilibrium (E_0) is the only stable steady state, and any discussion regarding the stability of an endemic state is irrelevant for this case, as confirmed by the continuous decline of the infected population toward eradication in Figure 1.

2) Stability of the endemic state

We changed the values of Education Campaign $\omega = 0.0, 0.1, 0.2, 0.3$, and 0.4 , and keep the values of the other values of parameters to be those given in Table 1. We obtained the eigenvalues, and basic reproductive numbers are $R_0 = 1.838, 1.654, 1.471, 1.287$, and 1.103 ($R_0 > 1$). All the eigenvalues are negative, and the basic reproductive number is greater than one, the endemic equilibrium point is local asymptotically stable, as shown in Figure 2 - 9.

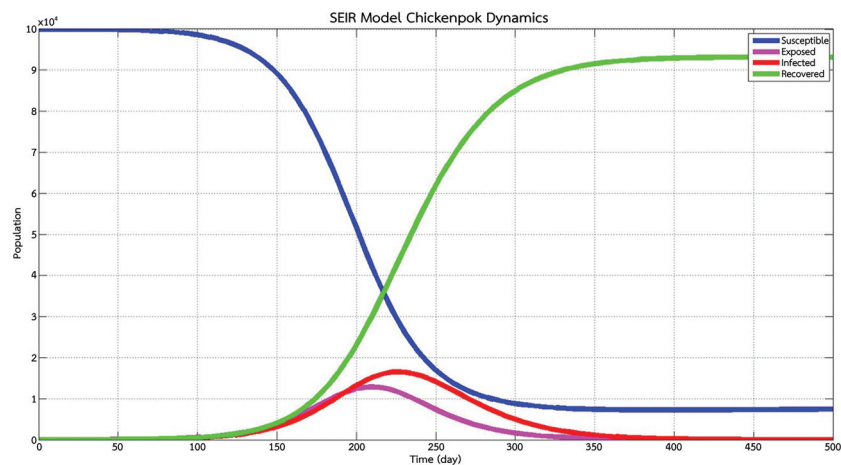


Figure 2 Time series of Susceptible human, Exposed human, Infected human and Recovered human on Education Campaign $\omega = 0$.

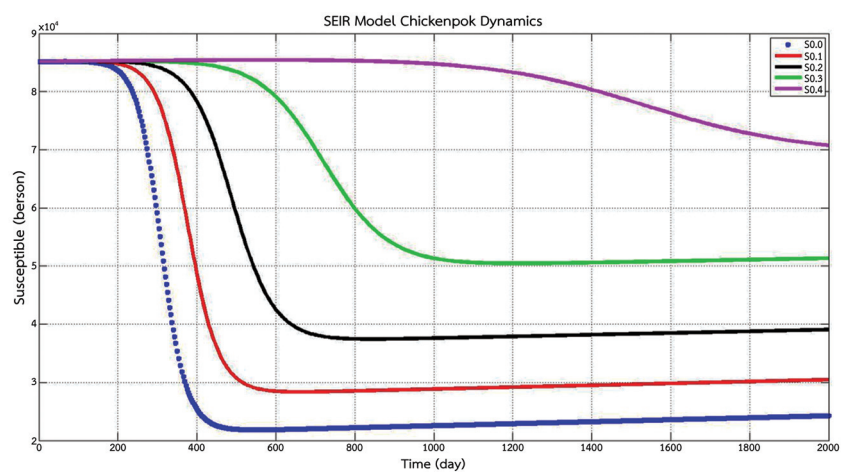


Figure 3 Time series of Susceptible human on Education Campaign $\omega = 0.0, 0.1, 0.2, 0.3$, and 0.4 .

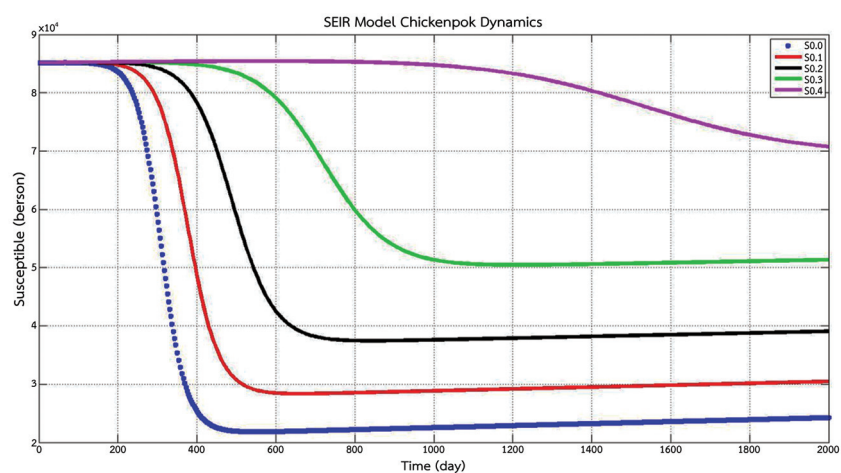


Figure 4 Time series of Exposed human on Education Campaign $\omega = 0.0, 0.1, 0.2, 0.3$, and 0.4 .

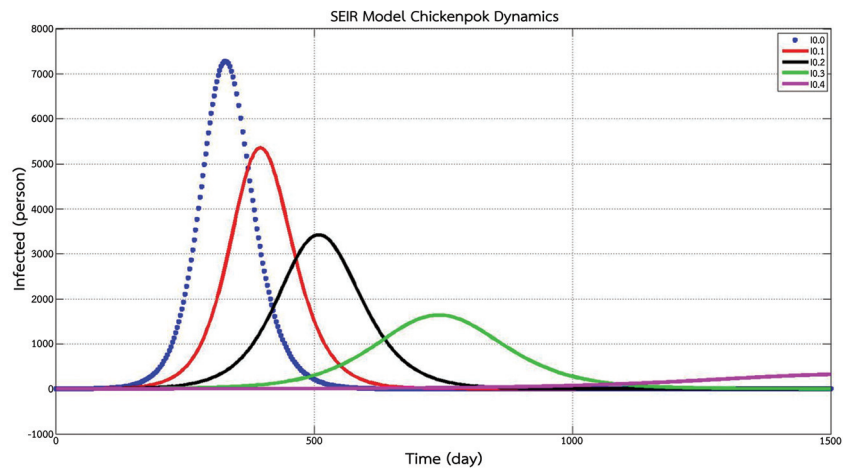


Figure 5 Time series of Infected human on Education Campaign $\omega = 0.0, 0.1, 0.2, 0.3$, and 0.4 .

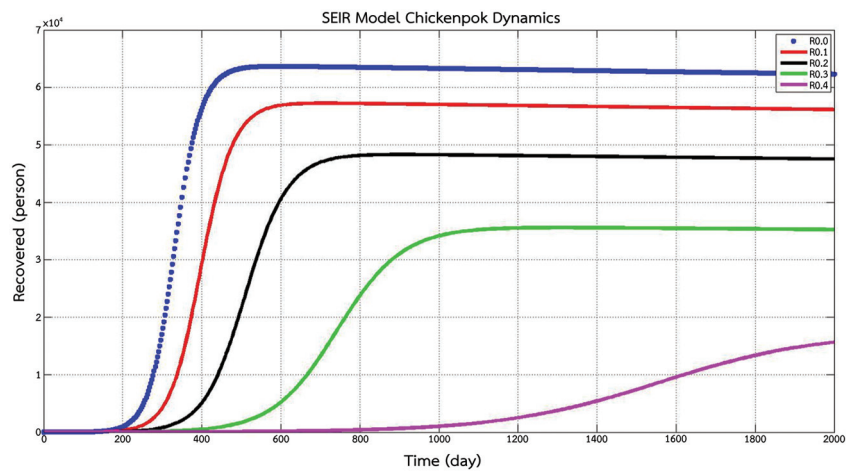


Figure 6 Time series of Recovered human on Education Campaign $\omega = 0.0, 0.1, 0.2, 0.3$, and 0.4 .

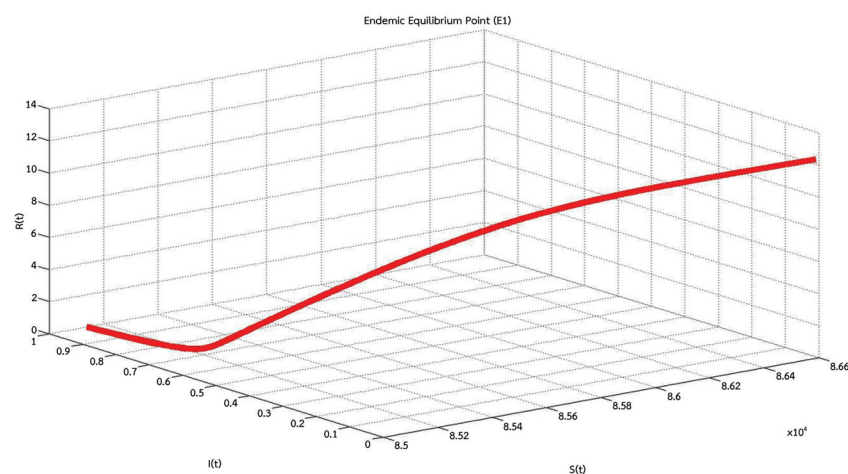


Figure 7 The relationship between (S) Susceptible human, (I) Infected human and (R) Recovered human. The solutions approach the endemic equilibrium state to the disease-free state.

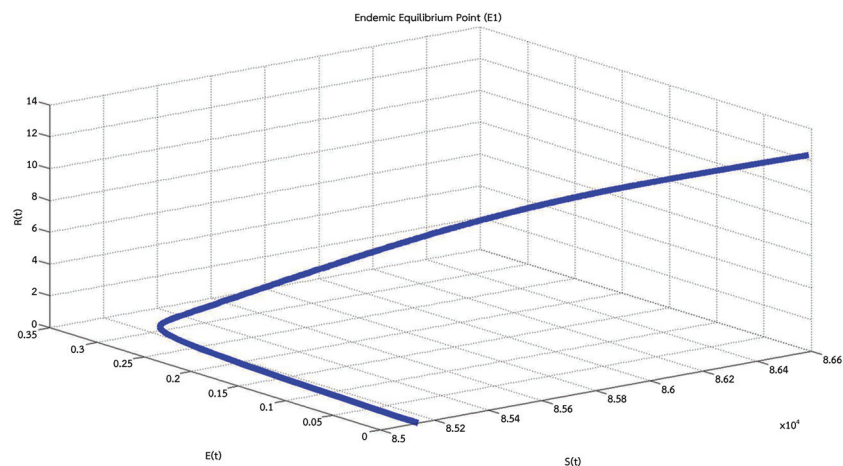


Figure 8 The relationship between (S) Susceptible human, (E) Exposed human and (R) Recovered human. The solutions approach the endemic equilibrium state to the disease-free state.

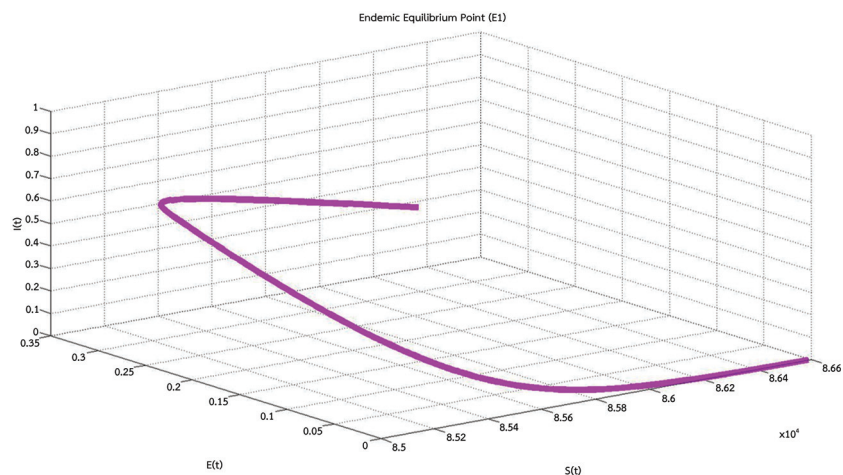


Figure 9 The relationship between (S) Susceptible human, (E) Exposed human and (I) Infected human. The solutions approach the endemic equilibrium state to the disease-free state.

The study found that the effectiveness of the education campaign is one of the factors affecting the dynamics of a mathematical model used to control the spread of chickenpox. If the at-risk population knows how to prevent chickenpox, fewer will spread the disease. If the population at risk of infection with chickenpox is knowledgeable about prevention methods, many individuals will help reduce the spread of the disease until there is no further transmission of chickenpox. At least 50 percent of the total population is at risk of infection with chickenpox and has knowledge about its prevention. This will aid in reducing the disease's spread until the infection stops spreading. This statistic highlights the importance of public health education in controlling outbreaks. By ensuring that a significant portion of the population understands how to prevent transmission, the overall health of the community can be safeguarded and the incidence of chickenpox can be significantly reduced.

In this study, we proposed the dynamics model of Chickenpox with considered the education campaign. We analyzed the model by the standard method. Also, we determined the equilibrium points and investigated the stability of the model. We obtained the basic reproductive

number using the next generation method. Further, we explored the impact of varying educational strategies on the spread of the disease, highlighting the importance of the education campaign in controlling outbreaks. Our findings suggest that targeted campaigns can significantly reduce transmission rates and improve overall health outcomes in the population.

The effectiveness of Education Campaign is the factor affecting the mathematical modelling. In epidemiology, the basic reproductive number is the number of secondary cases generated by a primary infectious individual. We employ the Roth-Hurwitz criteria to examine the stability of the system. The qualitative behaviors of this model are shown in Figure 1 - 4. We analyzed the model and optimal control and found that when the Education Campaign was 0.5, 0.6, 0.7, 0.8, and 0.9. The population at risk of infection with knowledge about the prevention of chickenpox is not less than 50 % of the total population and will contribute to the decrease in the spread of the disease until there is no further spread of infection. The evidence indicates that increasing the education campaign's effectiveness significantly enhances community awareness and engagement in preventive measures. This, in turn, leads to a more resilient population capable of resisting outbreaks. By fostering a culture of vigilance and proactive health practices, the long-term impact on public health can be profoundly positive, reducing the burden of chickenpox and similar infectious diseases. As a result, we can effectively reduce the overall incidence of chickenpox, promoting a healthier population and alleviating the burden on healthcare resources.

Conclusion and Suggestions

In conclusion, the results of this study demonstrate that the effectiveness of education campaigns plays a crucial role in controlling the transmission dynamics of chickenpox. When the effectiveness of the education campaign decreases, the number of infected individuals increases, resulting in a basic reproduction number greater than one ($R_0 > 1$), indicating persistent disease transmission within the community. Conversely, increasing the effectiveness of the education campaign reduces the number of infected individuals and leads to a basic reproduction number less than one ($R_0 < 1$), implying that the disease will eventually disappear from the population. These findings highlight the critical importance of maintaining effective educational campaigns to strengthen public awareness and preventive behaviors among at-risk populations. By enhancing the effectiveness of such interventions, communities can significantly reduce disease transmission and better protect vulnerable individuals. Furthermore, collaboration among local health authorities, schools, and community organizations can improve outreach activities, promote early recognition of symptoms, and encourage timely preventive actions, thereby contributing to the overall resilience and health of the community. Regarding the practical application of the proposed mathematical model, public health authorities may utilize the education campaign effectiveness parameter (ω) as a strategic indicator for planning and evaluating chickenpox control policies in schools and communities. Both the theoretical analysis and numerical simulations indicate that achieving an educational compliance level of at least 50 % ($\omega \geq 0.5$) can successfully reduce the basic reproduction number below the epidemic threshold ($R_0 < 1$), leading to disease eradication. In practical settings, decision-makers may estimate the actual value of (ω) through Knowledge, Attitudes, and Practices surveys conducted within target populations. If the observed

effectiveness level is lower than the mathematically determined threshold, public health interventions and educational campaigns can be intensified proactively to reduce the risk of future outbreaks. Although this study primarily focuses on theoretical analysis, the proposed model provides a useful framework for future epidemiological investigations. Future studies may incorporate real epidemiological data for model calibration and validation to improve predictive accuracy and enhance the practical applicability of the model in public health decision-making and chickenpox outbreak management.

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