Modeling the effects of education campaign on online game addiction of children and youth in Thailand

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ABSTRACT

Online game addiction could give negative impacts on children in many ways such as physical health, learning and behavior. These impacts could lead to a reduction in children's development in the aspects of physical, psychological, emotional and social development. Online game addiction is mainly caused by psychological problem, family or, social factors, and is mostly found in children and youth at the age of 15 – 24 years. Due to the fact that there is an increase in number of addicted gamers every year, therefore, in this research we explored the effect of education on online game addiction of children and youth in Thailand by analyzing mathematical model in the form of PAQ_tQ_p model. Mathematical program has been used for numerical analysis in this model and the basic reproduction number (R_0) is calculated. Our results show that an education by giving awareness of how games would give negative effects to children's lives could reduce a number of addicted online gamers. Hence, this could lead to an approach to control or reduce number of online game addiction in Thailand.

Keywords: online game addiction, mathematical model, numerical analysis, basic reproduction number

INTRODUCTION

The internet has been broaden since 1990s and has become an indispensable part of basic areas of life in the whole world e.g. education, business, entertainment industry and healthcare. With the growth of the internet, more people have accessed to online games. Online gaming therefore is a popular form of entertainment that influences the quality of life of players (Shen et al., 2011). Excessive gaming has been identified as a specific subtype of internet addiction (Block, 2008). Further, the American Psychiatric Association (APA) adds Internet Gaming as one of the potential disorders that needs to be treated. Unfortunately, a number of populations around the world who are both internet and online game addiction are increasing rapidly and have become national problem in many countries (King et al., 2011) including Thailand which is reported by the HealthyGamer.net in both 2012 and 2013. In addition, research shows that computer games are the most popular way of entertainment among 12-25 year old males (Kotick, 2001). A several studies show the negative consequences of internet and online game addiction together with the co-occurrence with mental health problems, physical health problems and academic failure (Grant et al., 2010; Cao et al., 2011; Salmon et al., 2011; Carli et al., 2012). In particular, playing online violent games can influences aggression in both the short and long term (Anderson et al., 2002) by influencing cognitive and emotional beliefs (Anderson et al., 2010). Hence, treatments or controlling the spread of online game addiction is essential to reduce the country problem in many aspects.

Prevention is the best solution in the game addiction (Argiris et al., 2014). Several studies have shown that one of the factor that could prevent the game addiction is education (Selim, 2014). Hence, education by giving awareness of how game addiction would affect to gamers' lives in lessen the decision of addicting to the game. This study therefore attempts to build a wider understanding about online game addiction of children and youth in Thailand through mathematical model. Hence, a mathematical model of online game addiction is developed. This model incorporates to education campaign to build awareness of the negative effect of online game addiction. The basic reproduction number is calculated. Stability analysis of dynamics within the model is performed theoretically and numerically to explore the effect of education campaign on the online game addiction situation.

MODEL FORMULATION

The transmission dynamics for online game addition is developed, the population is divided into four subgroups at time t : P is the number of potential addicted gamers, A is the number of addicted gamers, Q_t is the number of addicted gamers who temporarily quit playing games and Q_p is the number of addicted gamers who permanently quit playing games, with the total population size $N(\mathrm{t})$ where $N = P + A + Q_t + Q_p$. The schematic diagram of this model is shown below.

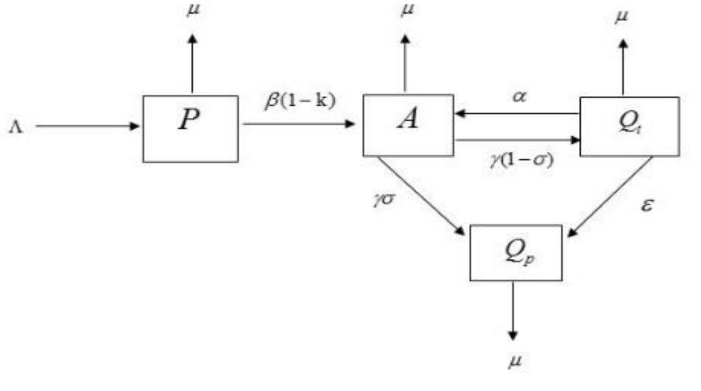

Figure 1: A schematic diagram of online game addiction dynamics.

The corresponding differential equations are

$$\frac{dP}{dt} = \Lambda - \mu P - \beta(1-\mathrm{k})PA \qquad (1)$$

$$\frac{dA}{dt} = \beta(1-\mathrm{k})PA + \alpha Q_t - \mu A - \gamma\sigma A - \gamma(1-\sigma)A \qquad (2)$$

$$\frac{dQ_t}{dt} = \gamma(1-\sigma)A - \mu Q_t - \alpha Q_t - \varepsilon Q_t \quad (3)$$

$$\frac{dQ_p}{dt} = \gamma\sigma A + \varepsilon Q_t - \mu Q_p \quad (4)$$

with initial conditions

$$P(0) \geq 0, A(0) \geq 0, Q_t(0) \geq 0, Q_p(0) \geq 0 \quad (5)$$

where β is the contact rate between potential addicted gamers and addicted gamers, k is the effectiveness of education campaign, α is the contact rate between addicted gamers and temporarily quitters who revert back to addicted gamers, γ is the rate of quitting playing games, $1-\sigma$ is the fraction of addicted gamers who temporarily quit playing games (at a rate γ), σ is the remaining fraction of addicted gamers who permanently quit playing games (at a rate γ), ε is the rate at which temporarily quitters become permanently quitters, μ is the natural death rate of human population in Thailand, Λ is the recruitment rate of human population in Thailand.

Boundary of Solution

Consider the total dynamics of human population which is $\frac{dN}{dt} = \Lambda - \mu N$, its solution is $N_t = \frac{\Lambda}{\mu} - \frac{(\Lambda - \mu N_0)}{\mu} e^{-\mu t}$. As $t \to \infty$, then $N_t \to \frac{\Lambda}{\mu}$. Therefore, the feasible solution set of system enter the region as $\Phi = \{(\mathrm{P}, \mathrm{A}, \mathrm{Q}_t, \mathrm{Q}_p) \in \Re_+^4 : \mathrm{N}_t \leq \frac{\Lambda}{\mu}\}$. Hence, every solution with condition to $\Re_+^4$, the region is positively invariant. It is sufficient to study the dynamics for online game addiction model in Φ.

Equilibrium Points

Addiction-free equilibrium state: this is when there is no addicted gamer,
$E_0 = (\frac{\Lambda}{\mu}, 0, 0, 0)$.

Addiction-present equilibrium state: this is when $A^* > 0$, we obtain
$E_1 = (P^*, A^*, Q_t^*, Q_p^*)$ where

$$P^* = \frac{\Lambda}{\mu + \beta(1-\mathrm{k})A^*}, \; A^* = [\frac{\Lambda(\mu+\alpha+\varepsilon)\beta(1-\mathrm{k})}{(\mu+\gamma\sigma+\gamma(1-\sigma))(\mu+\alpha+\varepsilon)-\alpha\gamma(1-\sigma)} - \mu]\frac{1}{\beta(1-\mathrm{k})},$$

$$Q_t^* = \frac{\gamma(1-\sigma)A^*}{\mu+\alpha+\varepsilon}, \; Q_p^* = \frac{\gamma\sigma A^* + \varepsilon Q_t^*}{\mu}.$$

The Basic Reproduction Number (R_0)

From the addiction-present equilibrium state, we then obtain the basic reproduction number (R_0) as $R_0 = \dfrac{\beta(1-\mathrm{k})\Lambda(\mu+\alpha+\varepsilon)}{\mu[(\mu+\alpha+\varepsilon)(\mu+\gamma\sigma+\gamma(1-\sigma))-\alpha\gamma(1-\sigma)]}$.

Stability Analysis

The local stability of this model is determined by constructing Jacobian matrix of the system of equations (1)-(4):

$$J(P,A,Q_t,Q_p) = \begin{bmatrix} -\mu-\beta(1-\mathrm{k})A & -\beta(1-\mathrm{k})P & 0 & 0 \\ \beta(1-\mathrm{k})A & \beta(1-\mathrm{k})P-\mu-\gamma\sigma-\gamma(1-\sigma) & \alpha & 0 \\ 0 & \gamma(1-\sigma) & -\mu-\alpha-\varepsilon & 0 \\ 0 & \gamma\sigma & \varepsilon & -\mu \end{bmatrix}. \quad (6)$$

Theorem 1. (local stability at E_0 **) If** $R_0 < 1$**,** the addiction-free equilibrium point (E_0) is locally asymptotically stable. If $R_0 > 1$ the addiction-free equilibrium point (E_0) is unstable.

Proof. The Jacobian matrix of the system of equations (1)-(4) at (E_0) is

$$J(\frac{\Lambda}{\mu},0,0,0) = \begin{bmatrix} -\mu & -\beta(1-\mathrm{k})\frac{\Lambda}{\mu} & 0 & 0 \\ 0 & \beta(1-\mathrm{k})\frac{\Lambda}{\mu}-\mu-\gamma\sigma-\gamma(1-\sigma) & \alpha & 0 \\ 0 & \gamma(1-\sigma) & -\mu-\alpha-\varepsilon & 0 \\ 0 & \gamma\sigma & \varepsilon & -\mu \end{bmatrix}. \quad (7)$$

The characteristic equation of above matrix is

$$(\mu+\lambda)(\mu+\lambda)[(\beta(1-\text{k})\frac{\Lambda}{\mu}-\mu-\gamma\sigma-\gamma(1-\sigma)-\lambda)(-\mu-\alpha-\varepsilon-\lambda)-\alpha\gamma(1-\sigma)]=0\,. \quad (8)$$

This gives $\lambda_1=\lambda_2=-\mu<0$. The rest of the equation is considered by using the Routh-Hurwitz criteria in the form of $\lambda^2+a_1\lambda+a_2=0$, where

$$a_1=2\mu+\gamma\sigma+\alpha+\varepsilon+\gamma(1-\sigma)-\beta(1-\text{k})\frac{\Lambda}{\mu},$$

$$a_2=\mu^2+\mu\alpha+\mu\varepsilon+\gamma\sigma\mu+\gamma\sigma\alpha+\varepsilon\gamma\sigma+\mu\gamma(1-\sigma)+\gamma\varepsilon(1-\sigma)-\beta(1-\text{k})\Lambda-\beta(1-\text{k})\frac{\Lambda}{\mu}(\alpha+\varepsilon),$$

this can be further determined that $a_1>0$ and $a_2>0$ when $R_0<1$, satisfying with Routh-Hurwitz criteria for $n=2$.

Theorem 2. (local stability at E_1) The addiction-present equilibrium point (E_1) is stable if $R_0>1$.

Proof. The addiction-present equilibrium point (E_1) exists when $R_0>1$ and the Jacobian matrix of the system of equations (1)-(4) at E_1 is

$$J(E_1)=\begin{bmatrix} -\mu-\beta(1-\text{k})A^* & -\beta(1-\text{k})P^* & 0 & 0 \\ \beta(1-\text{k})A^* & \beta(1-\text{k})P^*-\mu-\gamma\sigma-\gamma(1-\sigma) & \alpha & 0 \\ 0 & \gamma(1-\sigma) & -\mu-\alpha-\varepsilon & 0 \\ 0 & \gamma\sigma & \varepsilon & -\mu \end{bmatrix}. \quad (9)$$

The characteristic equation of $J(E_1)$ above is

$$(-\mu-\lambda)[(-W-\lambda)((\beta(1-\text{k})P^*-H-\lambda)(-C-\lambda)-\alpha\gamma(1-\sigma))-\beta^2(1-\text{k})^2A^*P^*(C+\lambda)]=0\,, \quad (10)$$

where $C=\mu+\alpha+\varepsilon$, $H=\mu+\gamma\sigma+\gamma(1-\sigma)$, and $W=\mu+\beta(1-\text{k})A^*$.

Consider equation (10) in the form of $\lambda^3+a_1\lambda^2+a_2\lambda+a_3=0$, we have

$a_1=H+C+W-\beta(1-\text{k})P^*$ where by calculation, it is always positive,

$a_2=CH+WH+WC+\beta^2(1-\text{k})^2A^*P^*-C\beta(1-\text{k})P^*-W\beta(1-\text{k})P^*-\alpha\gamma(1-\sigma)$,

$a_3=WCH+\beta^2(1-\text{k})^2A^*P^*C-WC\beta(1-\text{k})P^*-W\alpha\gamma(1-\sigma)$. Therefore, the addiction-present equilibrium point at E_1 is stable according to the Routh-Hurwitz criteria for $n=3$ ($a_1>0, a_3>0$ and $a_1a_2>a_3$) i.e. when

$a_3 = WCH + \beta^2(1-\text{k})^2 A^* P^* C > WC\beta(1-\text{k})\,\text{P}^* + W\alpha\gamma(1-\sigma)$, and $a_1a_2 > a_3$ i.e.

$$(H+C+W-\beta(1-\text{k})P^*)(CH+WH+WC+\beta^2(1-\text{k})^2 A^*P^* - C\beta(1-\text{k})P^* - W\beta(1-\text{k})P^* - \alpha\gamma(1-\sigma))$$
$$> WCH + \beta^2(1-\text{k})^2 A^*P^*C - WC\beta(1-\text{k})\,\text{P}^* - W\alpha\gamma(1-\sigma)\ .$$

Hence, when $R_0>1$, the addiction-present equilibrium point $E_1=(P^*, A^*, Q_t^*, Q_p^*)$ is stable when it satisfies the condition that. $a_3>0$ and $a_1a_2>a_3$ as above.

SENSITIVITY ANALYSIS

To determine what could be the best strategies to reduce online addiction gamer, the sensitivity indices of the model reproduction number, R_0, to parameters in this model is determined using the approach of Chitnis et al., (2008) and of Ngoteya et al., (2015). These sensitivity indices are calculated by using the technique of the normalized forward sensitivity index and are therefore given in Table 1. Results in Table 1 shows that the parameters that play a role in reducing R_0 in order are μ, k, γ and ε, respectively.

Table 1 Numerical values of sensitivity indices of R_0

Parameters	**Index at Paramete Value**	**Sign**
Λ	+1	positive
μ	-1.2604	negative
α	+0.0484	positive
σ	+0.1093	positive
ε	-0.0186	negative
β	+1	positive
γ	-0.4300	negative
k	-1	negative

NUMERICAL SIMULATION

In this section, the system of equations (1)-(4) is solved numerically. The parameters within this model are chosen as appropriate as shown in Table 2. The numerical results are shown in Figure 2.

Table 2 Parameters values used in numerical study

Parameter	Description	Value	Reference
Λ	The recruitment rate of human population in Thailand	8.61 per week	National Statistical Office, Thailand (2013)
μ	The natural death rate of human population in Thailand	0.483 per week	National Statistical Office, Thailand (2013)
α	The contact rate between addicted gamers and temporarily quitters who revert back to addicted gamers	0.15 per week	Research analysis of game addiction situation in Thailand.(2013)
σ	The remaining fraction of addicted gamers who permanently quit playing games (at a rate γ)	0.5	Estimate
ε	The rate at which temporarily quitters become permanently quitters	0.3 per week	Estimate
β	The contact rate between potential addicted gamers and addicted gamers	0.13 per week	Research analysis of game addiction situation in Thailand.(2013)
k	The effectiveness of education campaign	0.5	Variable
γ	The rate of quitting playing games	0.72 per week	Research analysis of game addiction situation in Thailand.(2013)

Figure 2(a) shows clearly that the effectiveness of education campaign (k) has a big impact on the number of addicted gamers. When k increases, there is a decrease in number of addicted gamers. From $k = 0.25$ to $k = 0.50$, it is noticed that only a small reduction of number of addicted gamers is obtained, whereas when $k = 0.75$, it shows a larger reduction in number of the addicted gamers and the epidemic time occurs slower. In addition, at $k = 0.9$, a significant decrease in number of addicted gamers is observed with a slower epidemic time i.e. there are approximately 300 addicted gamers less than those of the case where $k = 0.25$. Figure 2(b) and (c) gives similar results i.e. there is not much changes of number of Q_t and Q_p when k varies, however, when $k = 0.90$, it can be seen a noticeable reduction in both variables. This could be interpreted that although a number of addicted gamers is decreased due to the education campaign as shown in Figure 2(a), a number of gamers who quit either temporarily or permanently shows no change or a tiny reduction. This gives a positive situation because with higher effectiveness of education campaign, it leads to both decrease in number of addicted gamers and almost the same number of those gamers who like to quit either temporarily or permanently.

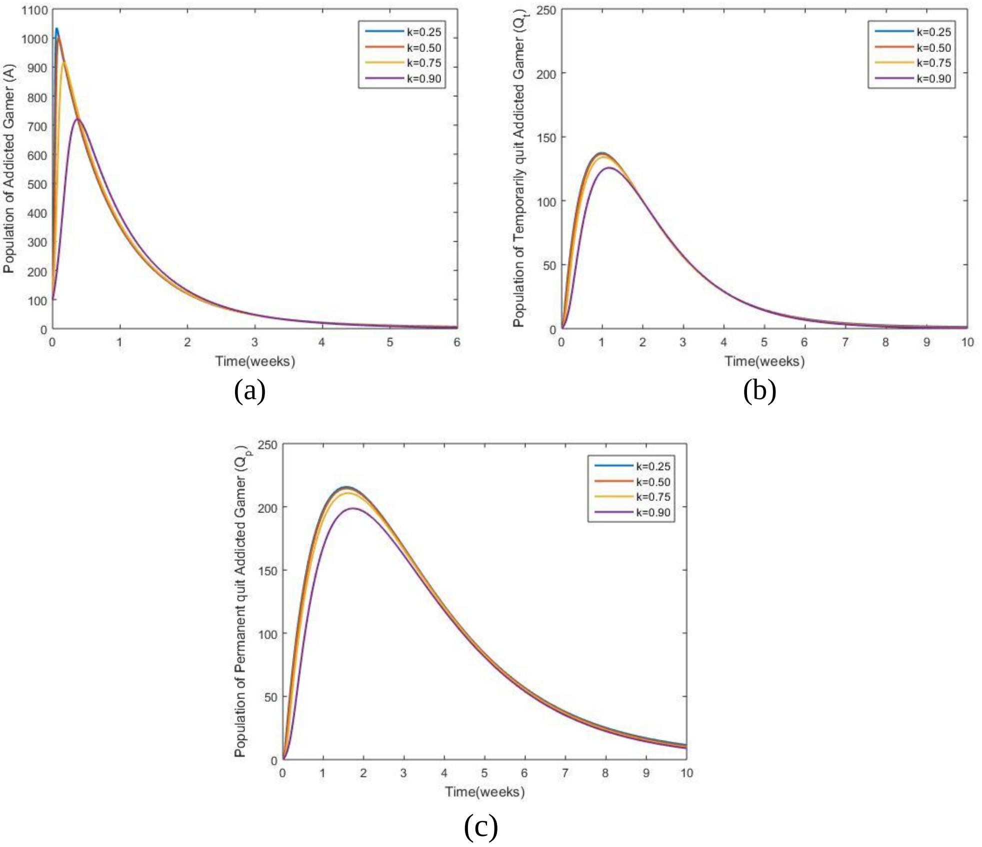

Figure 2: Numerical solution of system of equations (1)-(4) obtained using parameters: $\beta = 0.13$, $\Lambda = 8.61$, $\mu = 0.483$, $\alpha = 0.15$, $\sigma = 0.5$, $\varepsilon = 0.3$, $\gamma = 0.72$, where (a) is the population of addicted gamers (A), (b) is the population of addicted gamers who temporarily quit playing games (Q_t) and (c) is the population of addicted gamers who permanently quit playing games (Q_p), when k varies.

CONCLUSIONS

In this paper, we study the dynamics of online game addiction of Thai children and youth by developing PAQ_tQ_p model incorporating vital dynamics. The PAQ_tQ_p model is formed by four dimensional differential equations. In order to understand online game addiction situation, this model was analyzed qualitatively and there are two equilibrium points (addiction-free and addiction-present ones). The basic reproduction number is $R_0 = \dfrac{\beta(1-\mathrm{k})\Lambda(\mu+\alpha+\varepsilon)}{\mu[(\mu+\alpha+\varepsilon)(\mu+\gamma\sigma+\gamma(1-\sigma))-\alpha\gamma(1-\sigma)]}$ and it becomes a threshold condition for determining the stability of the model. If $R_0 < 1$, the addiction-free equilibrium point is locally asymptotically stable, where if $R_0 > 1$, it is unstable. As for addiction-present equilibrium point, it is locally asymptotically stable when its coefficients of characteristic equation satisfied the Routh-Hurwitz criteria. Furthermore, the numerical simulations suggest that the effectiveness of education campaign (k) has a significant effect on reducing a number of addicted gamers, and a tiny effect on both number of addicted gamers who temporarily and permanently quit playing games. This is confirmed by our sensitivity analysis showing an effect of k on reducing the number of addicted gamers. Hence, an increase in education campaign could be confirmed as a promising approach to ease the online game addiction of children and youth in Thailand.

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