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Numerical Solution of the SEIR Model for Online Game Addiction Problem by Homotopy Perturbation Methods in Students of Junior High School

Numerical Solution of the SEIR Model for Online Game Addiction Problem by Homotopy Perturbation Methods in Students of Junior High School

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Abstract. The purpose of this study was to obtain a numerical solution to the Suspected-Exposed-Infected-Recovered (SEIR) model for the problem of online game addiction in Junior High School 3 Makassar students. The SEIR model is built based on assumptions, then performs an analysis to determine the stability of the model and simulation to get a prediction of the number of students online games addiction. This research is an applied research, the method used to obtain the numerical solution of the SEIR model is the Homotopy Perturbation Method and uses secondary data. The results of this study are the numerical solution of the SEIR model of online game addiction with the homotopy perturbation method in Junior High School 3 Makassar students, the solution obtained shown that the number of students who are online games addiction can be suppressed by increasing parental supervision and also providing guidance and counseling. The results of the analysis shown that online game addiction as a result of online learning has increased, but can be suppressed with supervision from students' parents.

***Keywords*:** Online, problem, students

1. Introduction

Online games are games that are played online through the internet [1]. Games with online facilities via the internet not only offer fun game facilities, but players can communicate with other players around the world through chat and have translation facilities which greatly facilitate communication between players [2]. Online game fans in Indonesia reach 6 million people and around 40% are teenagers, which turns out to have a negative impact on them because they are unable to stop playing. A total of 64.45% of teenage boys and 47.85% of teenage girls aged 12-22 years who play online games stated that they are online games addiction [3]. Playing excessive games can cause death, in some cases people have died due to sitting in front of the computer for too long after playing games for an excessive period of time [4,5].

Research on online game addiction has been carried out by [6,7] which discusses online gaming problems from a social perspective but has not considered it from a mathematical point of view, then research on mathematical modelling has been carried out by [8, 9, 10, 11, 12, 13, 14, 15, 16, 17], but focuses on models of infectious diseases transmission. such as dengue fever, malaria, hepatitis, tuberculosis and covid-19.

Research on the mathematical model of online game addiction has been carried out by [18,19], but only focuses on models and simulations, then numerical solutions have been carried out using the homotopy perturbation method [20,21]. That studies have not examined the numerical solution to the problem of online game addiction using the homotopy perturbation method (MPH), then this study examines the numerical solution of the SEIR model [18] for the online game addiction problem of junior high school students using the homotopy perturbation method; model analysis and prediction of the number of online game addiction students can provide an overview of the parameters that have an effect on reducing the number of cases for online game addiction.

2. Research method

This research is an applied research. The SEIR model [15] on the problem of online game addiction was developed by analysing and finding a numerical model solution using the homotopy perturbation method [20,21]. The data used is secondary data on the number of online game addiction cases of Junior High School 3 Makassar students. The initial study of this research is to examine the SEIR model for the problem of online game addiction, then analyse the model to determine the stability of the system and the final part is to find a numerical solution for the SEIR model on the online game addiction problem of Junior High School 3 Makassar students with MPH to determine the prediction of the number of students online games addiction.

3. Result

The SEIR model on the problem of online game addiction can be interpreted in Figure 1, while the definitions and values of the variables and parameters used in the model are presented in Table 1:

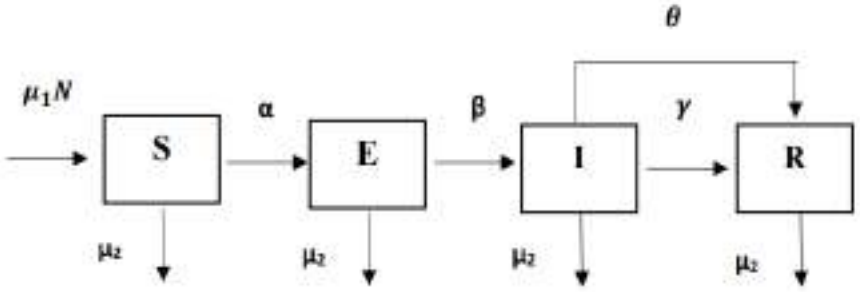

Figure 1. Flowchart of the SEIR model of online game addiction
Source: [18]

Figure 1 can also be interpreted into a mathematical model which is a nonlinear differential equation in system Equation (1)

$$\frac{dS}{dt} = \mu_1 N - (\alpha + \mu_2)S$$
$$\frac{dE}{dt} = \alpha S - (\beta + \mu_2)E \quad (1)$$
$$\frac{dI}{dt} = \beta E - (\gamma + \theta + \mu_2)I$$
$$\frac{dR}{dt} = (\gamma + \theta)I - \mu_2 R$$

Where $N = S + E + I + R$ is the total number of students in the population.

Table 1. Definition and values of Variables and parameters of SEIR model

Variable / Parameter	Definition	Value	Source
S	The number of students who are potentially addicted to playing online games	72	[18]
E	The number of students who started playing online games	77	[18]
I	The number of students who are addicted to playing online games	18	[18]
R	The number of students who stopped playing online games	9	[18]
μ_1	The rate of students who have online games on their gadgets	0.409	[18]
μ_2	The rate of students who do not have online games on their gadgets	0.097	[18]
α	The rate of students change from potentially addictive (susceptible) to trying to play online games (exposed)	0.438	[18]
β	The rate of students from trying to play (exposed) class to addicted online games (infected)	0.102	[18]
γ	The rate of student change from addiction (infected) to no longer playing (recovered)	0.051	[18]
θ	The effectiveness of parental supervision and guidance and counseling programs for students	1	[18]

3.1. SEIR model numerical solution using homotopy perturbation method (MPH)

The homotopy perturbation method is a combination of two methods, namely the perturbation method and the homotopy method, where both methods take an analytical approach to solve a non-linear problem, it's just that the linear factor in the perturbation method is not needed in the homotopy method. The steps to get a numerical solution using the homotopy perturbation method on the SEIR mathematical model of online game addiction are:

Given the initial conditions as in Equation (2):

$$\begin{aligned} S(0) &= x_0(t) = V_{1,0}(t) = x(0) \\ E(0) &= u_0(t) = V_{2,0}(t) = u(0) \\ I(0) &= y_0(t) = V_{3,0}(t) = y(0) \\ Z(0) &= z_0(t) = V_{4,0}(t) = z(0) \end{aligned} \tag{2}$$

Based on the theory of the perturbation homotopy method [20], a homotopy is built for the online game addiction model that satisfies the relationship as in Equation (3):

$$\begin{aligned} V_1' + x_0' + P\left(x_0' - \mu_1 + (\alpha + \mu_2)V_{1,0}\right) &= 0 \\ V_2' + u_0' + P\left(u_0' - \alpha x + (\beta + \mu_2)V_{2,0}\right) &= 0 \\ V_3' + y_0' + P\left(y_0' - \beta V_{2,0} + (\gamma + \theta + \mu_2)V_{3,0}\right) &= 0 \\ V_4' + z_0' + P\left(z_0' - (\gamma + \theta)V_{3,0} + \mu_2 V_{4,0}\right) &= 0 \end{aligned} \tag{3}$$

and has an initial approximation like Equation (4):

$$\begin{aligned} V_1 &= V_{1,0} + PV_{1,1} + P^2V_{1,2} + P^3V_{1,3} + P^4V_{1,4} + \cdots, \\ V_2 &= V_{2,0} + PV_{2,1} + P^2V_{2,2} + P^3V_{2,3} + P^4V_{2,4} + \cdots, \\ V_3 &= V_{3,0} + PV_{3,1} + P^2V_{3,2} + P^3V_{3,3} + P^4V_{3,4} + \cdots, \\ V_4 &= V_{4,0} + PV_{4,1} + P^2V_{4,2} + P^3V_{4,3} + P^4V_{4,4} + \cdots, \end{aligned} \tag{4}$$

Substituting Equations (2) and (4) into Equation (3), we get Equation (5)

$$\begin{aligned} V_{1,0}' + PV_{1,1}' + P^2V_{1,2}' + P^3V_{1,3}' + P^4V_{1,4}' + x_0' + P\left(x_0' - \mu_1 + (\alpha + \mu_2)V_{1,0}\right) &= 0 \\ V_{2,0}' + PV_{2,1}' + P^2V_{2,2}' + P^3V_{2,3}' + P^4V_{2,4}' + u_0' + P\left(u_0' - \alpha x + (\beta + \mu_2)V_{2,0}\right) &= 0 \end{aligned} \tag{5}$$

$V'_{3,0} + PV'_{3,1} + P^2V'_{3,2} + P^3V'_{3,3}+P^4V'_{3,4} + y'_0 + P\left(y'_0 - \beta V_{2,0} + (\gamma + \theta + \mu_2)V_{3,0}\right) = 0$
$V'_{4,0} + PV'_{4,1} + P^2V'_{4,2} + P^3V'_{4,3}+P^4V'_{4,4} + z'_0 + P\left(z'_0 - (\gamma + \theta)V_{3,0} + \mu_2 V_{4,0}\right) = 0$
Furthermore, grouping the same form of P, so that Equations (6), (7), (8), and (9) is obtained:

$$\begin{aligned} &P\left(V'_{1,1} - \mu_1 + (\alpha + \mu_2)V_{1,0}\right) = 0 \\ &P\left(V'_{2,1} - \alpha V_{1,0} + (\beta + \mu_2)V_{2,0}\right) = 0 \\ &P\left(V'_{3,1} - \beta V_{2,0} + (\gamma + \theta + \mu_2)V_{3,0}\right) = 0 \\ &P\left(V'_{4,1} - (\gamma + \theta)V_{3,0} + \mu_2 V_{4,0}\right) = 0 \end{aligned} \quad (6)$$

$$\begin{aligned} &P^2\left(V'_{1,2} - \mu_1 + (\alpha + \mu_2)V_{1,1}\right) = 0 \\ &P^2\left(V'_{2,2} - \alpha V_{1,1} + (\beta + \mu_2)V_{2,1}\right) = 0 \\ &P^2\left(V'_{3,2} - \beta V_{2,1} + (\gamma + \theta + \mu_2)V_{3,1}\right) = 0 \\ &P^2\left(V'_{4,2} - (\gamma + \theta)V_{3,1} + \mu_2 V_{4,1}\right) = 0 \end{aligned} \quad (7)$$

$$\begin{aligned} &P^3\left(V'_{1,3} - \mu_1 + (\alpha + \mu_2)V_{1,2}\right) = 0 \\ &P^3\left(V'_{2,3} - \alpha V_{1,2} + (\beta + \mu_2)V_{2,2}\right) = 0 \\ &P^3\left(V'_{3,3} - \beta V_{2,2} + (\gamma + \theta + \mu_2)V_{3,2}\right) = 0 \\ &P^3\left(V'_{4,3} - (\gamma + \theta)V_{3,2} + \mu_2 V_{4,2}\right) = 0 \end{aligned} \quad (8)$$

$$\begin{aligned} &P^4\left(V'_{1,4} - \mu_1 + (\alpha + \mu_2)V_{1,3}\right) = 0 \\ &P^4\left(V'_{2,4} - \alpha V_{1,3} + (\beta + \mu_2)V_{2,3}\right) = 0 \\ &P^4\left(V'_{3,4} - \beta V_{2,3} + (\gamma + \theta + \mu_2)V_{3,3}\right) = 0 \\ &P^4\left(V'_{4,4} - (\gamma + \theta)V_{3,3} + \mu_2 V_{4,3}\right) = 0 \end{aligned} \quad (9)$$

The solution to the differential equation is presented in Equation (10):

$$\begin{aligned} &V_{1,1} = \int_0^t \left(\mu_1 - (\alpha + \mu_2)V_{1,0}\right)ds \\ &V_{2,1} = \int_0^t \left(\alpha V_{1,0} - (\beta + \mu_2)V_{2,0}\right)ds \\ &V_{3,1} = \int_0^t \left(\beta V_{2,0} - (\gamma + \theta + \mu_2)V_{3,0}\right)ds \\ &V_{4,1} = \int_0^t \left((\gamma + \theta)V_{3,0} - \mu_2 V_{4,0}\right)ds \\ &V_{1,2} = \int_0^t \left(\mu_1 - (\alpha + \mu_2)V_{1,1}\right)ds \\ &V_{2,2} = \int_0^t \left(\alpha V_{1,1} - (\beta + \mu_2)V_{2,1}\right)ds \\ &V_{3,2} = \int_0^t \left(\beta V_{2,1} - (\gamma + \theta + \mu_2)V_{3,1}\right)ds \\ &V_{4,2} = \int_0^t \left((\gamma + \theta)V_{3,1} - \mu_2 V_{4,1}\right)ds \\ &V_{1,3} = \int_0^t \left(\mu_1 - (\alpha + \mu_2)V_{1,2}\right)ds \\ &V_{2,3} = \int_0^t \left(\alpha V_{1,2} - (\beta + \mu_2)V_{2,2}\right)ds \\ &V_{3,3} = \int_0^t \left(\beta V_{2,2} - (\gamma + \theta + \mu_2)V_{3,2}\right)ds \\ &V_{4,3} = \int_0^t \left((\gamma + \theta)V_{3,2} - \mu_2 V_{4,2}\right)ds \\ &V_{1,4} = \int_0^t \left(\mu_1 - (\alpha + \mu_2)V_{1,3}\right)ds \\ &V_{2,4} = \int_0^t \left(\alpha V_{1,3} - (\beta + \mu_2)V_{2,3}\right)ds \\ &V_{3,4} = \int_0^t \left(\beta V_{2,3} - (\gamma + \theta + \mu_2)V_{3,3}\right)ds \\ &V_{4,4} = \int_0^t \left((\gamma + \theta)V_{3,3} - \mu_2 V_{4,3}\right)ds \end{aligned} \quad (10)$$

and we have a special solution formula from the SEIR model homotopy perturbation method for online game addiction problem is obtained in Equations (11)-(14):

$$S(t) = \sum_{j=0}^{4} v_{1,j} = 72 - 38.11t + 20.79t^2 - 10.71t^3 + 6.14t^4 \quad (11)$$

$$E(t) = \sum_{j=0}^{4} v_{2,j} = 77 + 16.21t - 19.91t^2 + 13.07t^3 - 7.29t^4 \quad (12)$$

$$I(t) = \sum_{j=0}^{4} v_{3,j} = 18 - 12.81t + 16.35t^2 - 20.81t^3 + 25.22t^4 \quad (13)$$

$$R(t) = \sum_{j=0}^{4} v_{4,j} = 9 + 18.04t - 15.21t^2 + 18.66t^3 - 23.68t^4 \quad (14)$$

The MPH method of the SEIR model for online game addiction is calculated until the 10th iteration or more so as to produce a logical solution. The iteration results of SEIR model are presented in Table 2:

Table 2. The number prediction of SEIR model for game online problem by MPH

t	Suspected	Exposed	Infected	Recovered
0	72	77	18	9
1	71.25	77.32	17.75	9.35
2	70.51	77.62	17.51	9.70
3	69.79	77.90	17.29	10.03
4	69.08	78.18	17.07	10.35
5	68.39	78.43	16.86	10.67
6	67.71	78.68	16.67	10.97
7	67.04	78.91	16.48	11.27
8	66.39	79.13	16.30	11.56
9	65.76	79.34	16.12	11.84
10	65.13	79.54	15.96	12.12
11	64.52	79.73	15.80	12.39
12	63.92	79.90	15.65	12.65
13	63.33	80.07	15.50	12.91
14	62.76	80.23	15.36	13.16
15	62.19	80.37	15.22	13.41
16	61.64	80.51	15.09	13.65
17	61.10	80.64	14.96	13.89
18	60.57	80.76	14.84	14.12
19	60.04	80.88	14.72	14.35
20	59.53	80.98	14.60	14.57
21	59.03	81.08	14.49	14.79
22	58.54	81.17	14.39	15.00
23	58.06	81.26	14.28	15.21
24	57.59	81.34	14.19	15.42
25	57.13	81.41	14.10	15.62
26	56.68	81.48	14.01	15.81
27	56.23	81.54	13.93	15.99
28	55.80	81.59	13.87	16.16
29	55.38	81.64	13.81	16.33
30	54.97	81.69	13.77	16.47

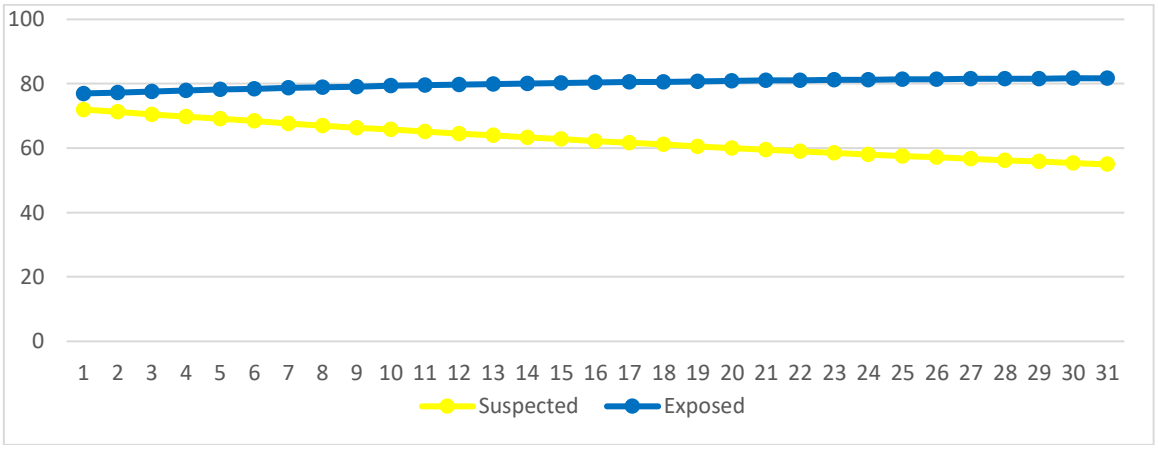

Figure 2. The number prediction of potential students (S) and starting to play online games (E)

The iteration results also be in the form of a graph shown in Figure 2 and Figure 3

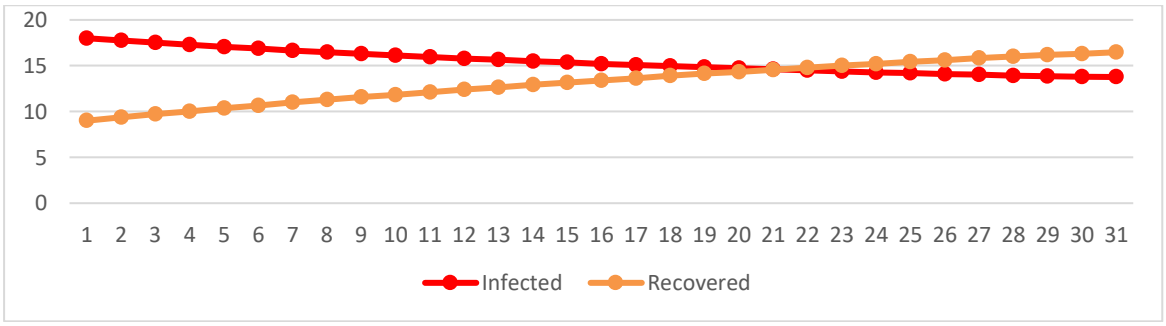

Figure 3. The number Prediction of students addicted (I) and quitting to online game addiction (R)

Based on Table 2 it is shown that using the homotopy perturbation method, the number of students who have the potential and addiction to online games continues to decreasing for the next days, on the contrary, the number of students who only try and stop playing online games continues to increasing for the next days. This shown that parental supervision and counseling guidance as parameters in the SEIR model for junior high school students are quite effective in reducing the number of students who are online games addiction.

In line with the explanation of Table 2, Figure 2 explains the same thing, the number of students who are potentially online games addiction as many as 72 students, then decreasing to 55 students a month later. Meanwhile, the number of students who started trying to play online games was 77 students and increasing to 82 students the following month. While Figure 3 explains that the number of students who are online games addiction is 18 students and decreasing to only 14 students in the following month, while the number of students who stop playing online games is 9 students and continues to increase to 17 students for the next month.

4. Discussion

Research on online game addiction problems that has been carried out by [6] shown that the lower the level of depression, the lower the level of online game addiction, and vice versa. Research results SEIR and SEIRS mathematical model for online game addiction by [18,19] focuses on model construction and model simulation where the model is derived from assumptions that form a system of differential equations. The results of this study focus on advanced analysis of the model [18] and the model numerical solutions by using the homotopy perturbation method where this method is able to provide solutions and predict the number of potential junior high school students, starting to try and become

online games addiction. The results of the study also given that the number of junior high school students who are online games addiction can be reduced by maximizing parental supervision and counseling guidance.

5. Conclusion

The concluded that the homotopy perturbation method can solve the SEIR model for the online game addiction problem of Junior High School 3 Makassar students. The results of the numerical solution of the SEIR model conclude that the number of student's online games addiction that occurs in students of Junior High School 3 Makassar tends to decrease significantly if parental supervision and counselling are carried out optimally. It can also be concluded that students who are online games addiction do not cause other students to become online games addiction.

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