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Study of The Lazy Nature of Physics Students Using The Quadratic Optimal Control Method

Dimas Kukuh Nur Rachim

Fakultas Sains, UIN Sultan Maulana Hasanuddin Banten, Indonesia

✉: dimas.kukuh@uinbanten.ac.id

Abstract

The lazy nature of learning is an obstacle in teaching and learning activities. The higher level of laziness will reduce the students learning achievement. This problem has motivated the author to make a mathematical model of student learning's lazy nature and analyze it. The lazy nature of learning is modeled to a discrete-time system $N(k+1) = AN(k) + BU(k)$ with $N(k)$, denotes a state vector of the lazy nature, $U(k)$ represents an input vector system in time, and denotes a coefficient matrix of $N(k)$ and $U(k)$. The optimal quadratic control method is applied in the model to analyze the system's stability and give the interpretation of the model based on the graphics info obtained during the simulation process. The feedback controller $K(k)$ is obtained as a result of optimizing the quadratic objective function. $K(k)$ a feedback controller's existence makes the lazy nature of learning physics students decrease from time to time, and the system becomes stable.

Keywords: lazy nature of learning, discrete-time system, optimal quadratic control

INTRODUCTION

The lazy nature of learning is an obstacle in teaching and learning activities (Kessels and Heyder 2020). In the digital era, students are faced with activities that can reduce the desire to learn, such as online games and social media activities (Acosta and Denham 2018). Each of these activities harms student learning patterns. Some of the negative effects of social media are student lose the habit of communicating face to face (Siddiqui and Singh 2016), the students lose concentration while studying because they open social media frequently (Raut and Patil 2016), and student need more time to complete assignments (Flanigan and Babchuck 2015). These three examples show that social media has negative impacts and fosters a lazy nature of learning reflected in various student behaviors.

This research intends to study the lazy nature of student learning through a mathematical approach (Sari et al. 2019). The model will be constructed using a discrete-time system (Liu, Yan, and Wei 2014). The Discrete-time system has been widely used to model daily events such as a traffic model (Rachim 2017), an economic model in Hu and Tu (2015), (Canto et al. 2008), population growth model (Haberman 1998), and several other models. Based on these studies, a discrete-time system is considered appropriate to model the lazy nature of student learning.

The lazy behavior modeled in a discrete-time system is then given the optimal quadratic control to analyze the system's stability and controllability (Bontempi, Birattari, and Bersini 2010). Furthermore, the analysis of the model will be presented based on the graphical info generated. The quadratic optimal control method is quite widely used to analyze systems such as the macroeconomic model (Engwerdah et al. 2009), network and Markov chain model (Kordonis and Papavassilopoulos 2014), model in game theory (Musthofa et al. 2015), and system descriptor model (Engwerda et al. and

Salmah 2008). The next section will discuss the research methodology and theoretical basis needed in this research.

METHODS

The research method used in this study is mathematical modeling based on the survey of related literature and accompanied by mathematical theorems. The study is organized out through three stages: (1) Study literature to find suitable models for modeling the lazy nature of learning, (2) Observes the lazy nature of student learning and the factors, and (3) Construct mathematical models and determine the value of parameters model based on factors obtained during the observation. This research aims to study students of Physics Study Program class 2019/2020 State Islamic University Sultan Maulana Hasanuddin Banten. The Mathematical models that will be built follow the flow chart defined by Pagalay (2009).

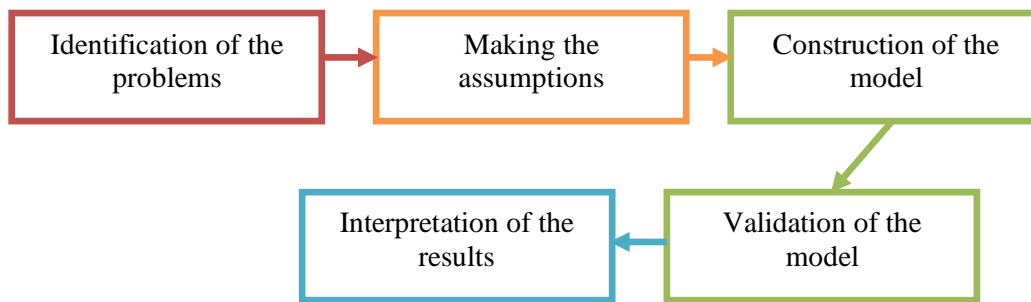


FIGURE 1. The Modeling Process Flow Chart

The lazy nature of learning model in this paper is constructed by using a discrete time system (Ogata 1995).

$$N(k + 1) = AN(k) + BU(k)$$

$$M(k) = CN(k) + DU(k), \tag{1}$$

where $N(k)$, $U(k)$, and $M(k)$ denote n dimensional state vector of the lazy nature, r dimensional input vector that represent student productivity in learning, an output vector of dimension m in time k . Consequently A, B, C and D are the matrix that have $n \times n, n \times r, m \times n$, and $m \times r$ dimension.

Furthermore, the feedback control applied in the discrete time system to analyze how the stability and controllability of the system. The feedback controller is obtained by optimizing the quadratic objective function that form defined in EQUATION (2) (Ogata 1995).

$$J = \frac{1}{2} N^*(K)SN(K) + \frac{1}{2} \sum_{k=1}^{K-1} [N^*(k)QN(k) + U^*(k)RU(k)] \tag{2}$$

where S and Q represent positive semi definite hermitian matrices with $n \times n$ dimension, also R denotes positive hermitian matrix with $r \times r$ dimension.

The matrices S , Q , and R are chosen as the weight of performance measure which caused by the state vector $N(k)$, the input vector $U(k)$, and the final state $N(K)$. Beside that, the terms of the

EQUATION (2) that are $\frac{1}{2} N^*(K)SN(K)$ represent the final condition of the model, $N^*(k)QN(k)$

known as the error system during the control process, and $U^*(k)RU(k)$ declared as the output of control signals. The next section of this paper will present the result and discussion about the analysis model.

RESULTS AND DISCUSSION

The modeling process starts with identifying the problem. Based on the observation the lazy nature of learning students is influenced by several factors such as the temptation to use social media, the density of activities on campus, dating with boy or girlfriend, uncomfortable classroom environment, and inadequate infrastructure. These factors cause the lazy nature of student learning can increase over time. It is assumed that each of student has a different level of laziness based on observations during the study and it represented by the diagonal matrix A with 30×30 dimension.

Formulate feedback control system $U(k) = -KN(k)$ which interprets student productivity in learning. This component is formulated to reduce the lazy nature of student learning expressed by a discrete-time system. According to the problem identification and assumptions, the discrete-time system of lazy nature follows this diagram.

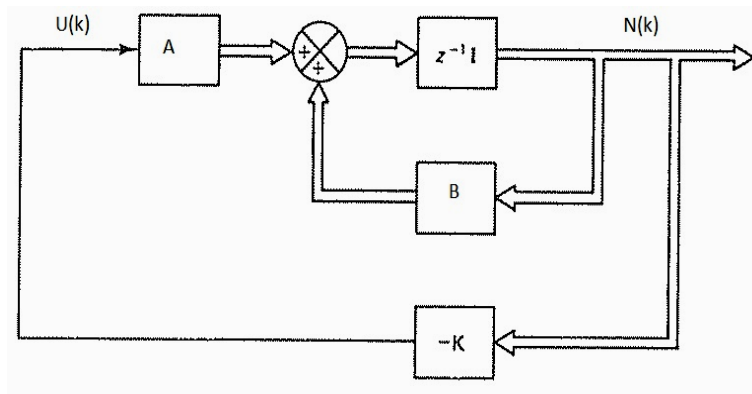


FIGURE 2. Discrete Time System Schema of The Lazy Nature of Learning (Ogata, 1995 : 403)

Based on a discrete time system of lazy nature in FIGURE 2. The mathematical modeling for the lazy nature of student learning can be modeled into a discrete time system in EQUATION (3).

$$\begin{aligned}
 N(k+1) &= AN(k) + BU(k) \\
 &= AN(k) + B[-KN(k)] \\
 &= AN(k) - BKN(k) \\
 &= [A - BK]N(k),
 \end{aligned}
 \tag{3}$$

Furthermore, defined the quadratic objective function to minimize performance index of the system that defined in EQUATION (2) such as

$$\min J = \min \left[\frac{1}{2} N^*(K)SN(K) + \frac{1}{2} \sum_{k=1}^{K-1} [N^*(k)QN(k) + U^*(k)RU(k)] \right]
 \tag{4}$$

Matrices $A, B, S, Q,$ and R represent 30×30 the diagonal matrix that entries contain parameters in TABLE 1.

TABLE 1. Parameters of A,B, Q,R, dan S

Subject	A	B	Q	R	S
S1	0.34	0.66	10	10	10
S2	0.38	0.62	10	10	10
S3	0.44	0.56	10	10	10
S4	0.44	0.56	10	10	10
S5	0.45	0.55	10	10	10

(Cont.) TABLE 1. Parameters of A,B, Q,R, dan S

Subject	A	B	Q	R	S
S6	0.51	0.49	10	10	10
S7	0.50	0.50	10	10	10
S8	0.41	0.59	10	10	10
S9	0.56	0.44	10	10	10
S10	0.58	0.42	10	10	10
S11	0.44	0.56	10	10	10
S12	0.37	0.63	10	10	10
S13	0.49	0.51	10	10	10
S14	0.46	0.54	10	10	10
S15	0.45	0.55	10	10	10
S16	0.45	0.55	10	10	10
S17	0.41	0.59	10	10	10
S18	0.50	0.50	10	10	10
S19	0.44	0.56	10	10	10
S20	0.40	0.60	10	10	10
S21	0.39	0.61	10	10	10
S22	0.58	0.42	10	10	10
S23	0.47	0.53	10	10	10
S24	0.45	0.55	10	10	10
S25	0.41	0.59	10	10	10
S26	0.50	0.50	10	10	10
S27	0.41	0.59	10	10	10
S28	0.43	0.57	10	10	10
S29	0.58	0.42	10	10	10
S30	0.53	0.47	10	10	10

The parameters in TABLE 1 are substituted into EQUATION (3) and (4) to solve the optimal quadratic control problem and transform the basic problem into a linear programming problem with EQUATION (3) as the objective function and EQUATION (4) represent the constraint. The Lagrange multiplier method is used to solve this problem and defined the Lagrange function as in EQUATION (5).

$$L = J - \sum_{k=0}^{n-1} \delta(k+1) [AN(k) + BU(k) - N(k+1)] \tag{5}$$

with δ denotes lagrange multiplier. The EQUATION (5) is rewrited to EQUATION (6) to ensure $L = L^*$

$$L = \frac{1}{2} N^*(n)SN(n) + \frac{1}{2} \sum_{k=0}^{n-1} [N^*(k)SN(k)] + U^*(k)RU(k) + \delta^*(k+1) [AN(k) + BU(k) - N(k+1)] + [AN(k) + BU(k) - N(k+1)]^* \delta(k+1). \tag{6}$$

The new objective function was obtained in EQUATION 6 such that the linear programming problem with constraint has transformed into the linear programming problem without restraint. The necessary condition for a partial derivative of L has been applied to solve EQUATION (6). The results are the EQUATION (7), (8), and (9).

$$\delta(k) = QN(k) + A^* \delta(k + 1) \tag{7}$$

$$U(k) = -R^{-1} B^* \delta(k + 1) \tag{8}$$

$$N(k + 1) = AN(k) - BR^{-1} B^* \delta(k + 1) \tag{9}$$

Furthermore, the ricati equation is constructed to solve the EQUATION (7), (8), dan (9) simultaneous. The Ricati Equation $\delta(k) = P(k)N(k)$ with P is 30×30 hermitian matrix. Substitute the ricati equation into EQUATION (7) and (8) to get

$$P(k)N(k) = QN(k) + A^* P(k + 1)N(k + 1) \tag{10}$$

$$N(k + 1) = AN(k) - BR^{-1} B^* P(k + 1)N(k + 1) \tag{11}$$

The EQUATION (11) can be simplified as

$$\left[I + BR^{-1} B^* P(k + 1) \right] N(k + 1) = AN(k) \tag{12}$$

Following this property $|I_n + CD| = |I_r + DC|$ can be shown $\left[I + BR^{-1} B^* P(k + 1) \right]$ has an invers such that the EQUATION (12) be able to become EQUATION (13)

$$N(k + 1) = \left[I + BR^{-1} B^* P(k + 1) \right]^{-1} AN(k) \tag{13}$$

Substitute EQUATION (13) into the EQUATION (10) to get the formula of $P(x)$ in explicit form as in EQUATION (14)

$$\left(P(k) - Q - A^* P(k + 1) \left[I + BR^{-1} B^* P(k + 1) \right]^{-1} A \right) N(k) = 0 \tag{14}$$

caused the value of $N(x)$ does not always zero then it can be ascertained the value of $P(k) - Q - A^* P(k + 1) \left[I + BR^{-1} B^* P(k + 1) \right]^{-1} A = 0$, as an implication

$$P(k) = Q + A^* P(k + 1) \left[I + BR^{-1} B^* P(k + 1) \right]^{-1} \tag{15}$$

The next step will be finding the feedback controller $K(k)$ that way is substitute the Ricati Equation and the EQUATION (7) into the EQUATION (8), recall the formula of the feedback controller $K(k)$ stisfy $U(k) = -KN(k)$ then we get

$$K(k) = R^{-1} B^* \left(A^* \right)^{-1} \left[P(k) - Q \right] \tag{16}$$

$$U(k) = - \left[R^{-1} B^* \left(A^* \right)^{-1} \left[P(k) - Q \right] \right] N(k) \tag{17}$$

The EQUATION (14), (16), and (17) will be solved together directly to get the values of the EQUATION (13) which present the lazy nature of each student. The simulation process is driven by MATLAB 2014a program with matrices A, B, S, Q , and R have taken from Table 1. The initial values of $N(0)$ is figured on $k0$ column. The output of simulation $N(k)$ to each student is figured in Table 2 such as.

TABLE 2. The level of lazy nature of physics students during ten times simulation process

Subject	k0	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
S1	1	0.23	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S2	1	0.27	0.07	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
S3	1	0.32	0.10	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
S4	1	0.32	0.10	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
S5	1	0.33	0.11	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00
S6	1	0.39	0.15	0.06	0.02	0.01	0.00	0.00	0.00	0.00	0.00
S7	1	0.38	0.15	0.06	0.02	0.01	0.00	0.00	0.00	0.00	0.00
S8	1	0.29	0.09	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
S9	1	0.45	0.20	0.09	0.04	0.02	0.01	0.00	0.00	0.00	0.00
S10	1	0.47	0.22	0.10	0.05	0.02	0.01	0.00	0.00	0.00	0.00
S11	1	0.32	0.10	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
S12	1	0.26	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S13	1	0.37	0.14	0.05	0.02	0.01	0.00	0.00	0.00	0.00	0.00
S14	1	0.34	0.12	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00
S15	1	0.33	0.11	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00
S16	1	0.33	0.11	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00
S17	1	0.29	0.09	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
S18	1	0.38	0.15	0.06	0.02	0.01	0.00	0.00	0.00	0.00	0.00
S19	1	0.32	0.10	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
S20	1	0.28	0.08	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
S21	1	0.28	0.08	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
S22	1	0.47	0.22	0.10	0.05	0.02	0.01	0.00	0.00	0.00	0.00
S23	1	0.35	0.12	0.04	0.02	0.01	0.00	0.00	0.00	0.00	0.00
S24	1	0.33	0.11	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00
S25	1	0.29	0.09	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
S26	1	0.38	0.15	0.06	0.02	0.01	0.00	0.00	0.00	0.00	0.00
S27	1	0.29	0.09	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
S28	1	0.31	0.10	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
S29	1	0.47	0.22	0.10	0.05	0.02	0.01	0.00	0.00	0.00	0.00
S30	1	0.41	0.17	0.07	0.03	0.02	0.01	0.00	0.00	0.00	0.00

Based on TABLE 2 the dynamics of the lazy nature of learning physics students can be observed from FIGURE 3, FIGURE 4, and FIGURE 5.

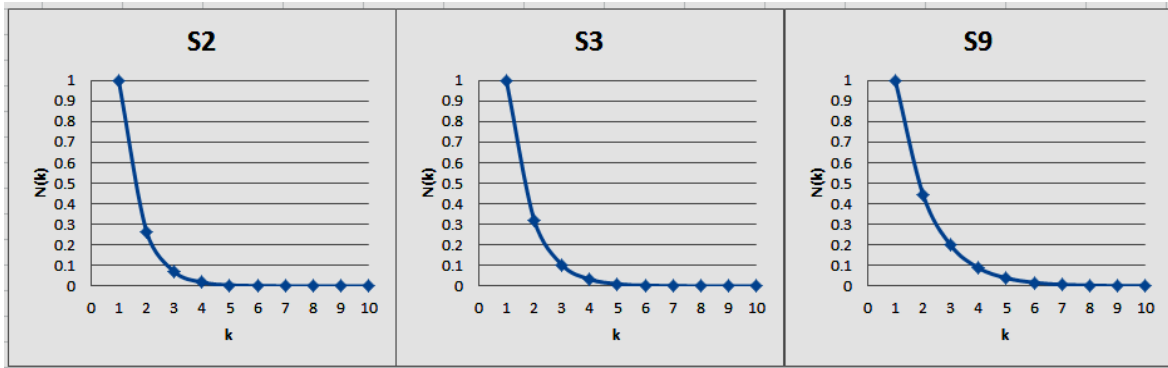


FIGURE 3. The level of the lazy nature of physics students, Subject No 2, 3, and 9.

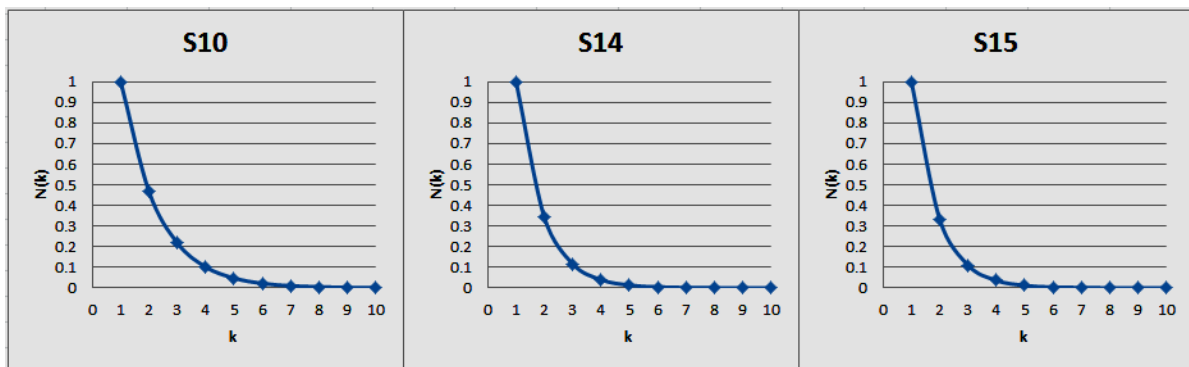


FIGURE 4. The level of the lazy nature of physics students, Subject No 10, 14, and 15.

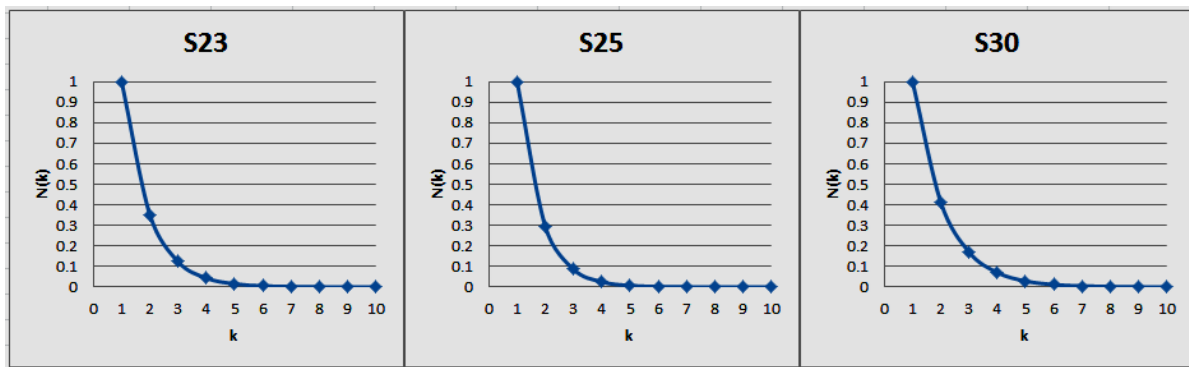


FIGURE 5. The level of the lazy nature of physics students, Subject No 23, 25, and 30.

The results of simulation process are figured on TABLE 2. The results represent the percentages of the lazy nature of learning physics students learning which consisting 30 students. In ten times period the results showed the percentages of the lazy nature of learning physics students has decreased and attended to zero. FIGURE 3, 4 and 5 show the value of some students listed in TABLE 2 of which are Subject number 2 has decreased percentage from 100%; 27%; 7%; 2%; 1% until 0%. Subject number 3 has decreased percentage from 100%; 32%; 10%; 3%; 1%; until 0%. Subject number 9 has decreased percentage from 100%; 45%; 20%; 9%; 4%; 2%; 1% until 0%. Subject number 10 has decreased percentage from 100%; 47%; 22%; 10%; 5%; 2%; 1%; until 0%. Subject number 14 has decreased percentage from 100%; 34%; 12%; 4%; 1%; until 0%. Subject number 15 has decreased percentage from 100%; 33%; 11%; 4%; 1%; until 0%. Subject number 23 has decreased percentage from 100%; 35%; 12%; 4%; 2%; 1%; until 0%. Subject number 25 has decreased percentage from

100%; 29%; 9%; 3%; 1%; until 0 %. Subject number 30 has decreased percentage from 100%; 41%; 17%; 7%; 3%; 2%; 1%; until 0 %.

According to the results, the percentages of the lazy nature of learning physics students have decreased from time to time and asymptotically stable. This outcome establishes the feedback controller $K(k)$ that applied to the system and has successfully stabilized the system. TABLE 3 presents the value of feedback controller $K(k)$ during the simulation period.

TABLE 3. The feedback controller $K(k)$ of physics students

Subject	k0	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10
S1	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.16	0.16
S2	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.17
S3	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.19
S4	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.19
S5	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.19
S6	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.23	0.20
S7	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.23	0.20
S8	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.18
S9	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.25	0.21
S10	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.26	0.21
S11	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.19
S12	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.17
S13	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.20
S14	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.19
S15	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.19
S16	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.19
S17	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.18
S18	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.23	0.20
S19	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.19
S20	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.18
S21	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.17
S22	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.26	0.21
S23	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.19
S24	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.19
S25	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.18
S26	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.23	0.20
S27	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.18
S28	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.20	0.19
S29	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.26	0.21
S30	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.24	0.20

The feedback controller $K(k)$ is 30 x 30 matrix that the diagonal entries contain the parameters in TABLE 3 for each student. During the observation, some things can increase students' motivation to counteract their lazy nature of learning, such as parents' motivation, comfortable learning environment, improvement in worship, and supportive learning colleagues (Kessels and Heyder 2020). The feedback controller $K(k)$ can be interpreted as the percentages of those good things. We can also give the students

the recommendation to apply the value of $K(k)$ their daily lives, so their lazy nature of learning can be decreased to zero and stable as the simulation process results.

CONCLUSION

The previous section discussed the lazy nature of learning physics students that modeled into a discrete-time system and applied the optimal quadratic control method. The system is modeled thirty physics students, which are expressed in the 30×30 matrix. The simulation process has shown the percentages of each student's lazy nature of learning have decreased from time to time and stable. The decrease was caused by giving the feedback controller $K(k)$, which is applied to the system. The feedback controller $K(k)$ can be interpreted as good things that can improve students' motivation. This research is limited to modeling the lazy nature of learning from thirty physics students. Future research can increase the number of subjects and construct a larger matrix size and input more external factors into the model.

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