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A Mealy Machine for Mechanic Dynamic Aesthetic (MDA) Gamification Model of Educator Career System in Indonesian Higher Education Institutions

Indah Dwi Mumpuni*, Tubagus Mohammad Akhriza, Sarifuddin Madenda, and Eri Prasetyo

***Abstract*—The purpose of this study is to develop a mechanic dynamic aesthetic (MDA) gamification model for higher education institutions (HEIs') educator career system (ECS). A mealy machine or finite state machine (FSM) is used to model the ECS gamification mechanic because the academic degrees targeted by the educators are finite and assumed to be the states that they must accomplish during their journey as professional educators. A program is created to simulate the Mealy machine and the results are checked by an ECS reviewer team. MDA-ECS is the result of a new ECS gamification model implemented in Indonesian HEIs. The proposed gamification model's mechanic is a five-tuple Mealy machine, which consists of four elements: (career) states, start states, inputs, outputs, and transitions. The four functional degrees (FDs): Associate Lecturer, Lecturer, Associate Professor, and Professor: represent the states of the machine. Credit points from the four aspects of 3D-HEI collected by the educator are the machine's inputs, while the grade of FDs, reward, and punishment are the outputs, and thus the gamification. The simulation showed that the mealy machine met the informational and affective aspects of the ECS regulation in Indonesian HEIs.**

***Index Terms*—Gamification, higher education, educator career system (ECS), mechanic–dynamic–aesthetic (MDA), finite state machine (FSM), mealy machine**

I. Introduction

Educator career development is one of the most important activities in Indonesian higher education institutions (HEIs) because educators carry out their responsibility of the Three Dharma of HEI (3D-HEI), namely teaching, research, and community engagement. Through some regulations, Indonesia's Ministry of Research, Technology, and Higher Education encourages educators to be actively involved in the 3D-HEI so that higher Academic Functional Degrees (FDs) can be attained in their career journey. The regulations are typically implemented by developing an Educator Career System (ECS) in conjunction with some local policies.

The lack of associate professors and professors in Indonesian HEIs is caused by the ECS implementation itself, which fails to attract and motivate educators to regularly improve their FDs up to the highest one, the professor. An effective method that an HEI's career management authority can use to solve this problem is to implement a gamification approach to the ECS because the FDs can be viewed as missions that educators must complete throughout their careers.

Gamification is not the same as gaming, but it is the process of transferring some positive aspects of gaming into nongame contexts, thus, it is referred to as gami-"fy"-ing [1]. A previous article distinguishes games and gamification in the design process [2]. A game is intended for entertainment, but gamification is intended for business purposes. A similar opinion was stated by Mora and Riera *et al.* [3], the purpose of gamification design elements is to enhance engagement in different contexts, while a game is directed to pure entertainment. To avoid a monotonous, bureaucratic, and boring user interface, interactive games are added to non-game systems in various fields, thus it is known as the gamification concept [4].

The Mechanic Dynamic Aesthetic (MDA) model is a popular gamification model. The *M* element contains game rules, such as reward and punishment systems, levels, and time limits. The *M* element creates the *D* element, which is the aesthetic of the game. Meanwhile, *A* is the player's response to the game, such as sensation, fantasy, challenge, and inspiration. However, a significant proposal for an ECS gamification model is still missing from scientific publications.

To address this gap, this article proposes an MDA-based gamification model for ECS, and to ensure generalizability, ECS policies implemented in Indonesian HEIs are used as a reference to develop the model. The proposal focuses on the mechanics that are modeled using a nondeterministic mealy machine, which is a finite state machine (FSM) that can generate outputs by reading specific inputs. The Mealy machine (M) is intended to move the educator (E) from one state or an FD (x) to the next state (> y) by using the credit points earned by E as input for *M*. As a result of reaching an FD, E receives a grade, some rewards, and punishments. The states are finite, thus, the Mealy machine with output fits to be the ECS gamification mechanic.

A computer program is created to implement the proposed Mealy machine. To simulate the machine in various real-world scenarios, the program is given three common cases: i) regular promotion, in which E can easily reach the highest FD; ii) delayed promotion, in which E is stuck on an FD for an extended period; and iii) jumping promotion, in which E jump twice in FDs from E's current FD. The goal of this study is to develop an MDA gamification method for the ECS that is represented or modeled using automatic language, specifically FSM.

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II. LITERATURE REVIEW

A. Gamification versus Game

Gamification is a concept that recently has attracted the interest of researchers [5] as it has been successfully incorporating gaming constructs in non gaming contexts by user engagement, understanding, and motivation [6]. The term “gamification” was coined by Nick Pelling in 2002 [7]. Gamification is not similar to a game but it is transferring some positive characteristics of a game into nongame ones; thus, it is called gami-“fy”-ing [2]. A previous study distinguishes games and gamification in the design process [8]. While the game is designed for entertainment, gamification is intended for business purposes. A similar opinion was stated in Mora and Riera *et al.* [3], that the purpose of gamification design elements is to enhance engagement in different contexts, whereas the game is directed to pure entertainment.

A game framework called mechanics–dynamics–aesthetics (MDA, was initially introduced in Hunicke and LeBlanc *et al.* [9]. It was a formal model for games and then became a framework for gamification, as described in Fig. 1.

Each element was explained as follows:

1) Mechanics, describing the components of the game, at the level of data representation and algorithms.
2) Dynamics, describing the run-time behavior of the mechanics acting on player inputs and outputs over time.
3) Aesthetics, describing the desirable emotional responses evoked in the player when interacting with the game.

The MDA framework is helpful when visualizing the designer-to-user relationship as it is a one-way relationship from the designer to the user [10]. Mechanics, dynamics, and aesthetics represent three different lenses in game design. From the designer’s perspective, mechanics produces dynamics, which then produces aesthetics. As such, several authors describe that the MDA started from the aesthetic first and then ended with the mechanics. According to Kim [2], aesthetics includes, for example, the feeling of fantasy (game as make-believe), sensation (game as sense-pleasure), narrative (game as drama), and challenges (game as obstacle course). This aesthetics can be understood as the different goals of the game itself and its components of fun [10]. Kim continues that dynamics are the design principles that create and support aesthetic experience, such as time pressure and opponent play is two game dynamics that create and support the aesthetic of challenge, whereas mechanics refers to the various actions, behaviors, and control mechanisms to the player within a game context, such as rules, levels, rewards, punishments, and points [9, 11]. For example, the mechanics of card games include shuffling, trick-taking, and betting, from which dynamics like bluffing can emerge [12].

Fig. 1. MDA-based gamification framework (adapted from Hunicke *et al.* [9]).

In other words, the MDA framework is a basic framework in game design, where the designer builds functions (mechanics), then provides different user interactions (dynamics), which bring emotions and experiences to the user (aesthetics). The generality of the MDA has led to its various interpretations. Mechanics–dynamics–emotions (MDE), as proposed by Robson and Plangger *et al.* [13], is a framework derived from MDA, in which the emotions replaced the aesthetics to describe the user experience when playing the game. As these aesthetic responses are largely computer game-specific, they tend to use the term “emotions” as it links better to the engagement outcomes that businesses can attain from employees and customers.

Another MDA derivation, design–dynamics–experience (DDE), is proposed in Walk and Görlich *et al.* [14] as the improvement of the derived framework. The authors explained that the mechanics of MDA is not sufficient to describe everything in a game that works mechanically. Therefore, the design is proposed to replace the mechanics. Similarly, aesthetics in the MDA is replaced by the users. Previous study also reviewed several game frameworks proposed between 2004 and 2017, such as Elemental Tetrad [15] which was well-accepted by academics and practitioners as a modern game design framework. The framework proposed mechanics, technology, story, and aesthetics as the design components. Earlier, another well-accepted framework is called the Design, Play, and Experience (DPE) framework, which is particularly defined for “Serious game” as proposed in Winn [16]. DPE concerns that such designs do not simply comprise gameplay mechanics, but also include pedagogical contents for learning, characters, settings, story narratives, and a user interface.

B. Gamification in Career Development

Gamification implementation in career development can be found in some publications. Work gamification can be regarded as an approach to create real-time access to performance information and make tasks more enjoyable [1]. The purpose of the implementation is to foster human motivation and performance [17, 18], effectiveness [1], enhance employee engagement [19], self-directed [20], and critical thinking [21]. Allowing the employees to do “self-branding” using social learning or e-learning tools will create enterprise winners in the emerging economic environment in the information age [22, 23]. A previous study suggested the psychological need for satisfaction [17]. They implemented the self-determination theory in improve the employee’s participation to the system. It includes the need for competence, a sense of efficiency, and success. On the other hand, it also fulfills the need for autonomy or the psychological freedom and volition to fulfill a certain task and the need for social relatedness or the sense of belonging, attachment, and care to a group of significant others while interacting with the environment [24].

The use of gamification within the workplace in Lowman [25] is driven by the need of collecting information about potential employees and identifying talent. It is a tool for the HR division to identify, attract, and retain talent. Gamification is used as a strategy to lead the users’ behavior by increasing their self-contribution to a system [26, 27].

Furthermore, a previous study explained the differences between traditional and gamification ways in a corporate’s performance management system [1]. In the informational aspect, gamification provides more visible access, comparable, and immediate feedback for the employees about their performance, whereas the traditional approach only provides access to performance information without added features. In the affective aspect, the traditional approach only focuses on the efforts to make work more intrinsically motivating, whereas gamification uses game features to make tasks more enjoyable.

Previous studies explained that game components are used in work gamification, for example, points, badges, and levels [1, 28]. In games, points and levels can be accrued for the performance of specific tasks necessary for the ultimate goals (e.g., defeating the Ninja king or the final boss). Achievement badges and the ability to "level up" have the purpose to display mastery in certain areas [29]. Other components include leader board that ranks the players, a performance graph, meaningful stories, avatars, visual representation of the players, and teammates that improve the dynamics of the game [17, 30–32].

Although there is enough literature discussing gamification implementation in career development, publications regarding gamification frameworks for ECS are still not found. Thus, this gives this work a motivation to propose the new gamification framework for ECS, particularly those that are applied in Indonesia's HEIs.

C. Finite State Machine in Game Mechanics

The mechanics consist of rules and mechanisms that control the players' movement from one state to another. Among the other mechanisms, the FSM is usually used to do such functionality. According to Dormans [8], games can and often are understood as state machines: an initial state or condition, actions of the player, and often the game can bring new states until an end state is reached.

The domination of FSM usage in game artificial intelligence is also described in Sulaiman and Liliana *et al.* [33], whereas its usage to design states in an adventure game is found in Dormans [34] (Fig. 2). FSM can control the game behavior when a state is reached by the player [35], and different states can direct the player into a different game experience from the other states (Fig. 3).

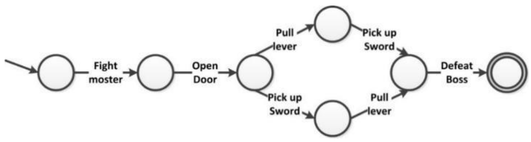

Fig. 2. FSM for an adventure game (adapted from Dormans [34].

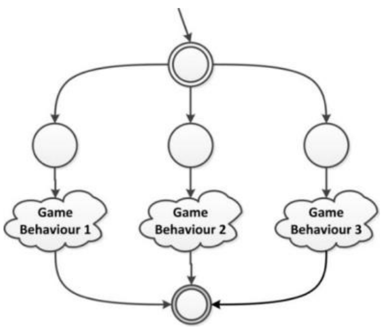

Fig. 3. FSM describing different game behaviors (adapted from Moreno-Ger *et al.* [35]).

Using a Deterministic FSM or the Mealy machine, a player (L) at a current state (SA) is directed to some next-states (SB) to obtain certain outputs. A Mealy machine (M) is defined in [22, 36] as a 5-tuple $M (Q, s0, I, O, 5)$ consisting of a finite of states (Q), an initial state ($s0 \in Q$), a finite set of input (I), a finite set of output (O), a transition function ($\delta: Q \times I \rightarrow O \times Q$) that maps each current state and input pair to output and next state pair. A graphical representation of M is given in Fig. 4, in which a transition edge from SA to SB is labeled by the input/output pair x/a, where $I = \{x, y\}$, $O = \{a, b\}$, $Q = \{q0, q1, q2\}$, and $s0 = q0$. As an example, $\delta (q0, x) = (a, q1)$ means that from the current state of $q0$, the state is moved to $q1$ and obtains a as the output when reading x as an input. Fig. 4 can also be represented by a transition table as shown in Table I.

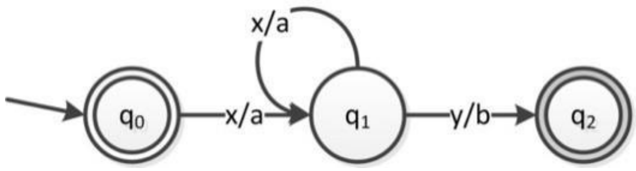

Fig. 4. The graphical representation of a Mealy machine.

TABLE I: THE TRANSITION TABLE OF MACHINE *M*

Current state	Next state	Input ^{I}	Output ^{O}
q0	*q1*	*x*	*a*
q1	*q1*	*x*	*a*
q1	*q2*	*y*	*b*

D. Indonesian Government Regulations on Educator Career System

The proposed gamification model is developed by referring to some official regulations about the ECS system published by the Ministry of Research, Technology, and Higher Education of the Republic of Indonesia. Some relevant regulations used to develop the model are:

1) Career of a professional educator is officially divided into four FDs, Associate Lecturer (AL), Lecturer (L), Associate Professor (AP), and Professor (P) in ascending order. Before being an AL, one can start a career as a Teacher (T) without having any FD.
2) To reach one FD, an educator must have a particular formal educational degree (*Ed* $\in$ *{bachelor (B), master (M), or Doctoral (D)}*). A different Ed has a different credit point, shortened as *cpEd*, whereas $CP_B = 100$, $CP_M = 50$, and $CP_D = 50$.
3) An FD can be reached after passing some years of working period (Wp).
4) An educator must do some activities related to certain 3D-HEI. The first aspect of 3D-HEI is teaching activities (TA). The components of it are classes teaching, thesis supervising, giving a scientific speech at a scientific forum, acting as principal of an institutional board, etc. Each of TA's components has a credit point or is symbolized as $CP_{1,i}$. In Indonesian HEI's ECS, CP_{ED} is a part of TA. The second one is research activities (RA). The components are doing research, publishing journal articles, conference proceeding articles, publishing books, etc. RA also has a credit point, symbolized as $CP_{2,j}$. The third one is Community engagement activities (CA) and the components are doing community engagement, giving service to social community institutions, acting as a committee of community activities, etc. The credit point of each of CA's components is symbolized as $CP_{3,k}$. Lastly, the fourth aspect is additional activities, which

include being a member of professional associations, acting as editorial board of a scientific journal, etc. Each of the components has a credit point, symbolized as *cp4,l*.

5) A variable called *Kum* is a metric that sums up the credit points of all components of 3D-HEI's aspects above and ED's credit point as defined in Eq. (4), in which CP_i, i = 1, …, 4 is obtained by Eq. (5). CP_{ED} is included in CP_1.
6) $Kum = CP_1 + CP_2 + CP_3 + CP_4$ (4)

$$CP_1 = CP_{ED} + \sum_{i=1,\ldots m} CP_{1,i};\ \sum_{j=1,\ldots n} CP_{2,j};\ \sum_{k=1,\ldots p} CP_{3,k};\ \sum_{l=1,\ldots q} CP_{1,l} \quad (5)$$

$$totalKum = totalKum + Kum \quad (6)$$

7) Each FD has several inherent grades and they are the other target that the educators are set to achieve in their professional career journey (Table II).

TABLE II: THE PAIR (FD, GRADE), TOTALKUM, AND THE PERCENTAGE OF 3D-HEI'S REQUIRED COMPONENTS

No.	FD	Minimum Ed	Grade	Minimum totalKum	CP_1	CP_2	CP_3	CP_4
1	AL	B	IIIa	100	≥55	≥25	≤10	≤10
2		M	IIIb	150				
3	L	M	IIIc	200	≥45	≥45	≤10	≤10
4		M	IIId	300				
5	AP	M	Iva	400	≥40	≥40	≤10	≤10
6		D	IVb	550				
7		D	IVc	700				
8	P	D	IVd	850	≥35	≥45	≤10	≤10

8) To reach a certain FD, the educator should obtain totalKum, which is the aggregate of all Kum he/she obtained (Eq. (6)). The totalKum and the percentage of each $CP_{i,\ i} = 1, \ldots, 4$ required for each pair (FD, Grade) are given in Table II. For example, supposedly E is an AL (IIIb) with *totalKum = 160* and he/she wants to continue to the Lecturer (IIIc) with *totalKum = 200*; thus, E should obtain at least 40 credit points with a percentage of *CPi, i = 1, …, 4* as defined in row 3 of Table II.
9) E's movement to the next state can be divided into three ways:
   - Regular FD promotion. When E moves to one FD, E obtains a grade corresponding to the respective D. For example, from AL to L, from L to AP, and from AP to P
   - Regular grade promotion, that is, when E stays in the current FD, but E moves to the next grade corresponding to the FD
   - Special FD promotion. It is when E jumps two FDs, and E obtains a grade corresponding to the FD. For example, from AL to AP and from L to P.

III. METHODS

A. The Proposed MDA-ECS Gamification Model

Among the existing gamification frameworks, the MDA is referred to as the basic concept to develop a gamification model for ECS. It is the fundamental concept of all frameworks reviewed in this article.

The proposed model is MDA-ECS and its mechanics are developed by referring to some ECS regulations. Its goal is to increase educators' participation in the ECS in the HEI. Fig. 5 depicts the proposed MDA-ECS with an educator's features as the input of ECS gamification. The educator's current FD, Kum, Wp, and Ed are the standard features. If the next state is achieved, a grade and some rewards can be given to him/her. However, punishment can be reduced if the educator achieves something positive in the HEI.

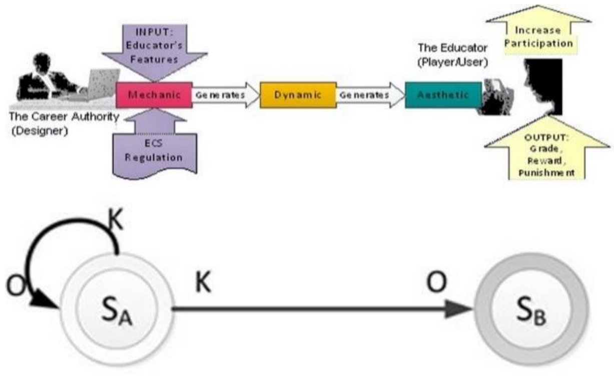

Fig. 5. The illustration of the proposed MDA-EC.

The mechanical design is made by rules that can prompt educators to act. In this study, the state movement or transfer of an educator's career in the future is modeled into a finite state machine (SA, SB, K, O) based on the ECS used in universities (Fig. 1). SA and SB are both states representing an academic functional position. Each component is described in greater detail below:

Levels: this is a task that an educator must complete. There are four academic positions in Indonesian regulations, Associate Lecturer (AL), Lecturer (L), Associate Professor (AP), and Professor (P). However, one more status is included, the Teaching Personnel (T), which is the status of an educator who begins his or her career without any academic position. In other words,

S = {T, AL, L, AP, P}

SA, or Initial State, is the academic position held by an educator when he/she begins his/her career at a university. Thus, S0, T, AL, L, AP, and P imply that he/she can begin his/her career in one of S's academic positions.

K set contains the components from FSM Mechanics that are the input of 3D of HEIs, namely teaching, research, community service, and other supporting elements.

O = {Goal, Reward, Punishment}

Set O is a group in the lecturer career system that serves as one of the future targets for educators (Table III). The proposed MDA-Mealy ECS's machine transition table contains:

Point: If an educator in his current State (T, AL, L, AP, P) achieves the next Stata with an academic degree (GA, M, D), a certain period of work, and a certain grade of Cumulative Kum points, he/she can get another level of achievement.

Reward: this is an achievement obtained by an educator if he/she completes the 3D of HEIs activities and met the cumulative credit score for the target academic position.

Punishment: This is a punishment/sanction that will be imposed if the educator stagnates in the previously held academic position, exceed the deadline for submitting an academic position, and does not meet the cumulative credit score from 3D-HEIs.

TABLE III: MEALY MACHINE'S TRANSITION TABLE OF THE PROPOSED MDA-ECS

Transition type	Current FD	Next FD	$Feat = \{(Ed, Wp, \sum cp_{1,i}, \sum cp_{2,j}, \sum cp_{3,k}, \sum cp_{4,l}, totalKum)\}$	Output
1	T	T	$Feat_1 = \{(B, \geq 1y, < 8, < 10, \geq 5, 0, < 100)\}$	No grade
2	T	AL	$Feat_2 = \{(\geq B, \geq 1y, \geq 8, \geq 10, \geq 5, 0, \geq 100)\}$	IIIa
3	T	AL	$Feat_{3A} = \{(\geq M, \geq 1y, \geq 8, \geq 10, \geq 5, 0, \geq 150)\}$	IIIb
4	AL	AL	$Feat_{3B} = \{(\geq M, \geq 1y, \geq 8, \geq 10, \geq 5, 0, \geq 150)\}$	IIIb
5	AL	L	$Feat_4 = \{(\geq M, \geq 2y, \geq 4, \geq 20, \geq 5, \geq 5, \geq 200)\}$	IIIc
6	AL	L	$Feat_5 = \{(\geq M, \geq 2y, \geq 4, \geq 30, \geq 5, \geq 5, \geq 300)\}$	IIId
7	AL	AP	$Feat_6 = \{(\geq D, \geq 2y, \geq 4, \geq 35 \geq 5, \geq 10, \geq 400)\}$	IVa
8	L	L	$Feat_7 = \{(\geq M, \geq 2y, \geq 4, \geq 30, \geq 5, \geq 5, \geq 300)\}$	IIId
9	L	AP	$Feat_8 = \{(\geq D, \geq 2y, \geq 3, \geq 40, \geq 5, \geq 5, \geq 400)\}$	IVa
10	AP	AP	$Feat_9 = \{(\geq D, \geq 2y, \geq 3, \geq 40, \geq 5, \geq 5, \geq 550)\}$	IVb
11	L	P	$Feat_{10} = \{(\geq D, \geq 10y, \geq 3, \geq 45, \geq 5, \geq 10, \geq 850)\}$	IVd
12	AP	AP	$Feat_{11} = \{(\geq D, \geq 2y, \geq 3, \geq 45, \geq 5, \geq 5, \geq 700)\}$	IVc
13	AP	P	$Feat_{12} = \{(\geq D, \geq 3y, \geq 3, \geq 45, \geq 5, \geq 5, \geq 850)\}$	IVd
14	P	P	$Feat_{13} = \{(\geq D, \geq 2y, \geq 3, \geq 50, \geq 5, \geq 5, \geq 1050)\}$	IVe
15	*Q*	*q*	*NoFeat*	Same grade

B. The Mealy Machine for the Mechanics

The main function of the mechanics in MDA-ECS is to move an E from the current FD to the next one and to give E some outputs corresponding to the FD. The movement is modeled using a nondeterministic Mealy machine as it meets the ECS conditions. There are inputs and outputs in the ECS as well, which fits the Mealy machine concept. Nonetheless, before the machine is formally defined, the transition from the current FD to the next one and the corresponding output are given in Table III.

However, only the grade is defined as the output in Table III, as it is determined in the regulation, whereas reward and punishment are defined by each HEI. Table III also provides a more detailed description of *totalkum* that should be achieved to obtain a particular FD and grade.

1) Since the true number of activities of 3D-HEI is large, the purpose is to simplify the simulation process. Credit points $\{cp_{1,i}\}$ are summed up into $\sum cp_1$, and symbols "<, ≥" are used to represent that the sum is less than or greater than/equal with a certain value. Analogically, $\{cp_{2,j}\}$ is summed up into $\sum cp_2$, $\{cp_{3,k}\}$, into $\sum cp_3$, and $\{cp_{4,l}\}$ into $\sum cp_4$.
2) There are 15 transition types defined for M in which each type corresponds to the element of *Feat* set $\{Feat_1, Feat_2, Feat_3, Feat_4, \ldots, Feat_{14}\}$ respectively, and these *Feats* are the input of M.
3) Each $Feat_i$ defines the minimum value (represented by "≥") of elements in $(Ed, Wp, \sum cp_{1,i}, \sum cp_{2,j}, \sum cp_{3,k}, \sum cp_{4,l}, totalKum)$ that are required to reach the next FD. For example, from T to AL and to obtain Grade IIIb, an educator's feature must meet $d \geq B$, $Wp \geq 1$y, $\sum cp_{1,i} \geq 8$, $\sum cp_{2,j} \geq 10$, $\sum cp_{3,k} \geq 5$, $\sum cp_{4,l} \geq 0$, and the $totalKum \geq 150$. Each element may have various values to the educator's achievement, which means that there are many possible ways to move from a current to the next FD.
4) Credit points are in a real number, given by a reviewer team, and legalized by the HEI's principal.
5) In the current ECS regulation (since 2012), the lowest FD (and grade) that an educator can obtain is the AL (IIIb), from T (or $Feat_{3A}$). Beforehand, the lowest FD was AL (IIIa) and many educators in Indonesian HEIs are still an AL (IIIa), so Table III still includes such regulations as $Feat_2$. However, those who hold AL (IIIa) can improve their degree to IIIb by satisfying $Feat_{3B}$.
6) $Feat_1$ is an educator who still holds a bachelor's degree and has no FD. Based on the current regulation, that E cannot move forward to any FD. However, in the transition graph (Fig. 6), $Feat_1$ is not depicted.
7) Type 15 represents a condition when an educator's FD (i.e., q) or grade does not move forward to a higher FD or grade and occurs when E achievement cannot fulfill some components of the next FD's *Feat*, expressed as *NoFeat*.

The formal definition of the Mealy machine for ECS is defined as a 5-tuple $M(Q,s_0,Feat,0,S)$, with M graphically represented in Fig. 6 and each of the components is defined as the following.

1) A finite set Q of FD includes T, or $Q = \{T,AL,L,AP,P\}$.
2) Initial career state is any of $s_0 \in Q$, which means that the career can start from any member of Q. Sometimes when starting the professional career as an educator in an HEI, someone possibly has had an FD from the former HEI he/she was working for.
3) A finite set of features $Feat = \{(Ed, Wp, \{\sum cp_{1,i}\}, \{\sum cp_{2,j}\}, \{\sum cp_{3,k}\}, \{\sum cp_{4,l}\}, totalKum)\}$ of an educator E, where $\{cp_{1,i}\}$is a set of credit points of components of the I^{th} aspect of 3D-HEI. Set *Feat* becomes the input of M, and, understandably, that E's features represent the achievement of E the moment he/she applies for the career promotion.
4) A finite set of output O = {Goal, Reward, Punishment}. In Fig. 6, the output is represented as (*grade, r, p*).
5) A transition function $\delta: Q_c \times Feat \rightarrow Q_n \times 0$, where Q_c and Q_n are the current and next FD, respectively, as defined in Table III. The double circle represents the type 15 transition when an educator is stuck at the current FD and grades for a period.

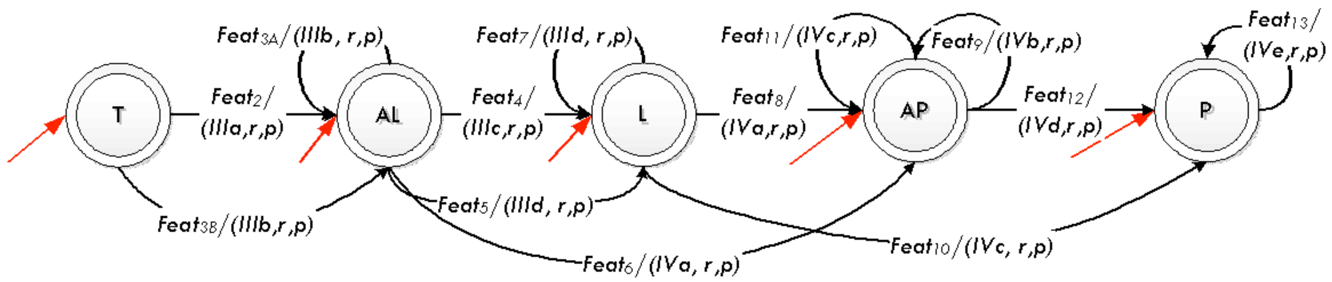

Fig. 6. The Mealy machine of MDA-ECS.

Property 1: Mealy machine for ECS in Indonesian HEI is nondeterministic. Proof: It is said to be non-deterministic because it can go to more than one next state from a current state by reading the same input [37]. Analogically, an AL with a feature set that allows him/her to jump two FDs to AP can also shift one FD to L with the same feature set. This is comparable to an E who can switch to one FD (AP) or two (Professor) while maintaining the same feature set. MDA-ECS is thus a nondeterministic Mealy machine.

Property 2: Until an E quits the gamification, he or she will remain at the current FD and grade. Proof: Because FSM with output has output rather than a final or accepting state; E can stop (or stuck) at any FD and respective grade until he/she leaves the gamification, such as by resigning, retiring, or passing away.

C. *Experimental Works Design*

A computer program for the Mealy machine is created to simulate its work on career promotion processing. The simulation is carried out by an ECS reviewer team from an Indonesian university, allowing the correctness of the program's career promotion to be directly assessed. Several assumptions are used in the simulation. One round process is a process of determining whether an E's current feature set satisfies a Feat in Table III. To make the simulation more interactive, the constraint mark (cons) and the Wp and Ed values are entered manually before the team generates one round. The constraint is used to demonstrate the correctness of the Mealy machine in the following situations: i) E can smoothly reach all next FD or the value of the cons equal to N (no constraint); ii) an L (IIId) cannot continue to AP (IVa) because some features do not satisfy the requiring Feat or the cons equal to D (delay); and iii) an AL (IIId) jumps 2 FDs. The simulation begins with SA = T with no grade, progresses to AL (IIIb), and concludes with Professor with the highest grade (IVe). The program checks whether the *totalKum* and all CPs can satisfy the highest Feat for the same FD. Thus, if someone can jump two FDs, the program will take advantage of this opportunity. If not, the Feat one level lower is evaluated, and so on.

The Associate Lecturer track (Fig. 7) explains how an E can reach AL (IIIb), from T. A box describes a process that randomly generates the values of Cp_1 to Cp_2 and calculates the *Kum*. Three conditions are checked. If E's features satisfy Feat3A, then E obtains AL with grade IIIb; otherwise, E should try to improve all CPs values to satisfy Feat3 and get punished if there is no improvement. As described in the flowchart, if an FD is reached, then rewards are added (Rew++), and the punishment is reduced (Pun—) for E, and vice versa; if E is stuck at an FD for a long period, then certain punishment (Pun++) is applied to E.

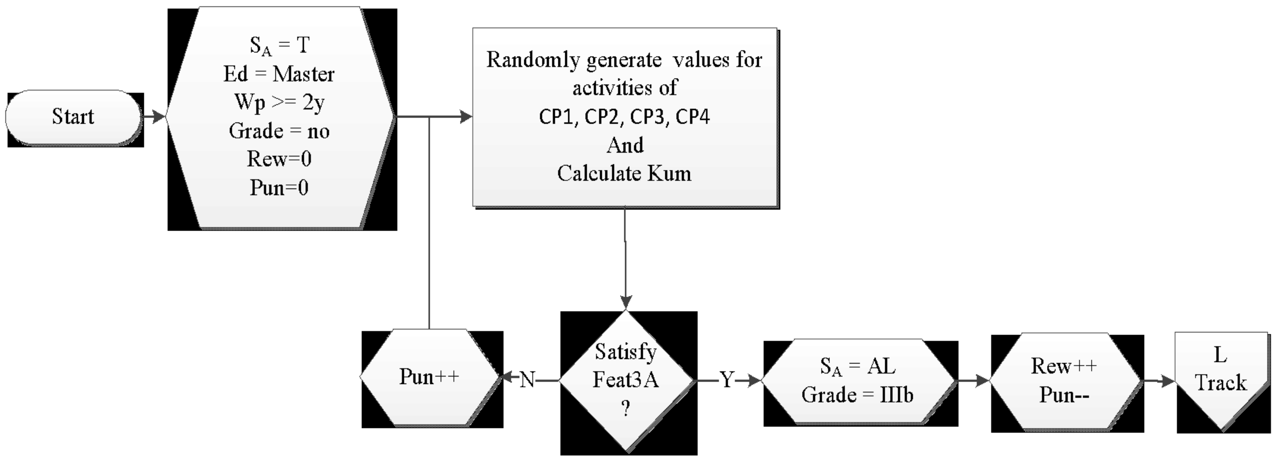

Fig. 7. The flowchart of the associate lecturer track.

The Lecturer track (Fig. 8) explains the ways to reach L from AL. E is supposed to be having a doctoral degree and working for at least 2 years as AL. After the new Kum value is obtained, it is checked if E's features can satisfy $Feat_6$. If so, then E can jump two FDs to AP (Iva), and then E goes to the AP track with special additional four points (Rew+ = 4). Otherwise, E continues to L (IIId) or L (IIIc) if $Feat_5$ or $Feat_4$ is satisfied, respectively. However, if no *Feat* is met, but E is stagnant at the current FD, then the punishment is applied. The decision box does not process the criteria if the current feature set has met a *Feat* defined in the box. For example, if $Feat_4$ is met and SA = L (IIIc), if the next feature meets $Feat_4$ once again, then the decision box goes to the "N" branch. It means that E does not have any significant feature improvement because E is being stuck at the current FD for some time, and then the punishment will be applied.

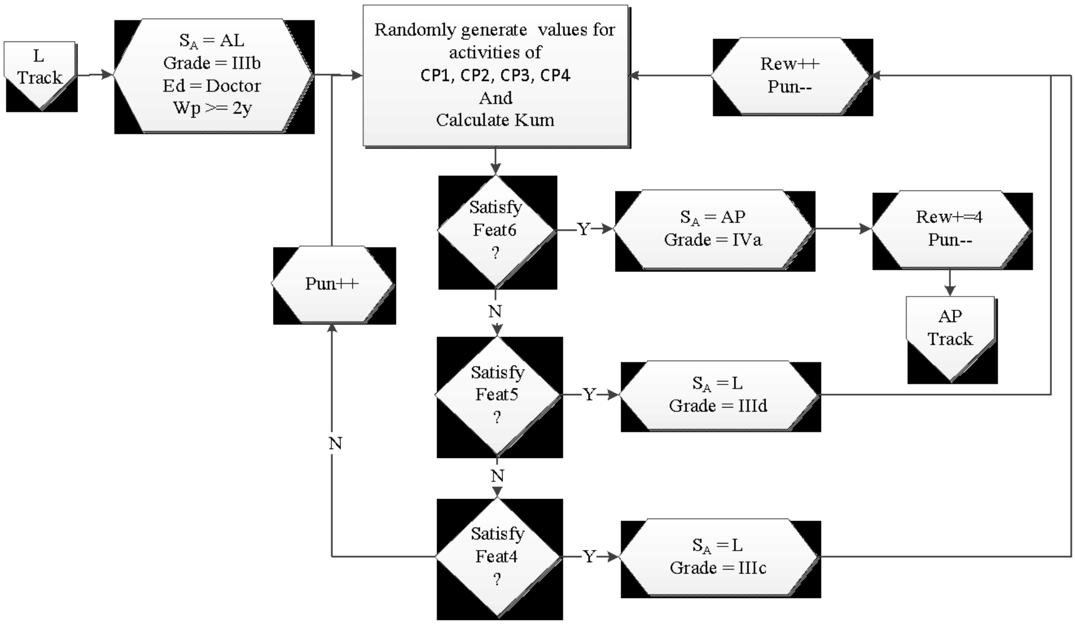

Fig. 8. The flowchart of the Lecturer track.

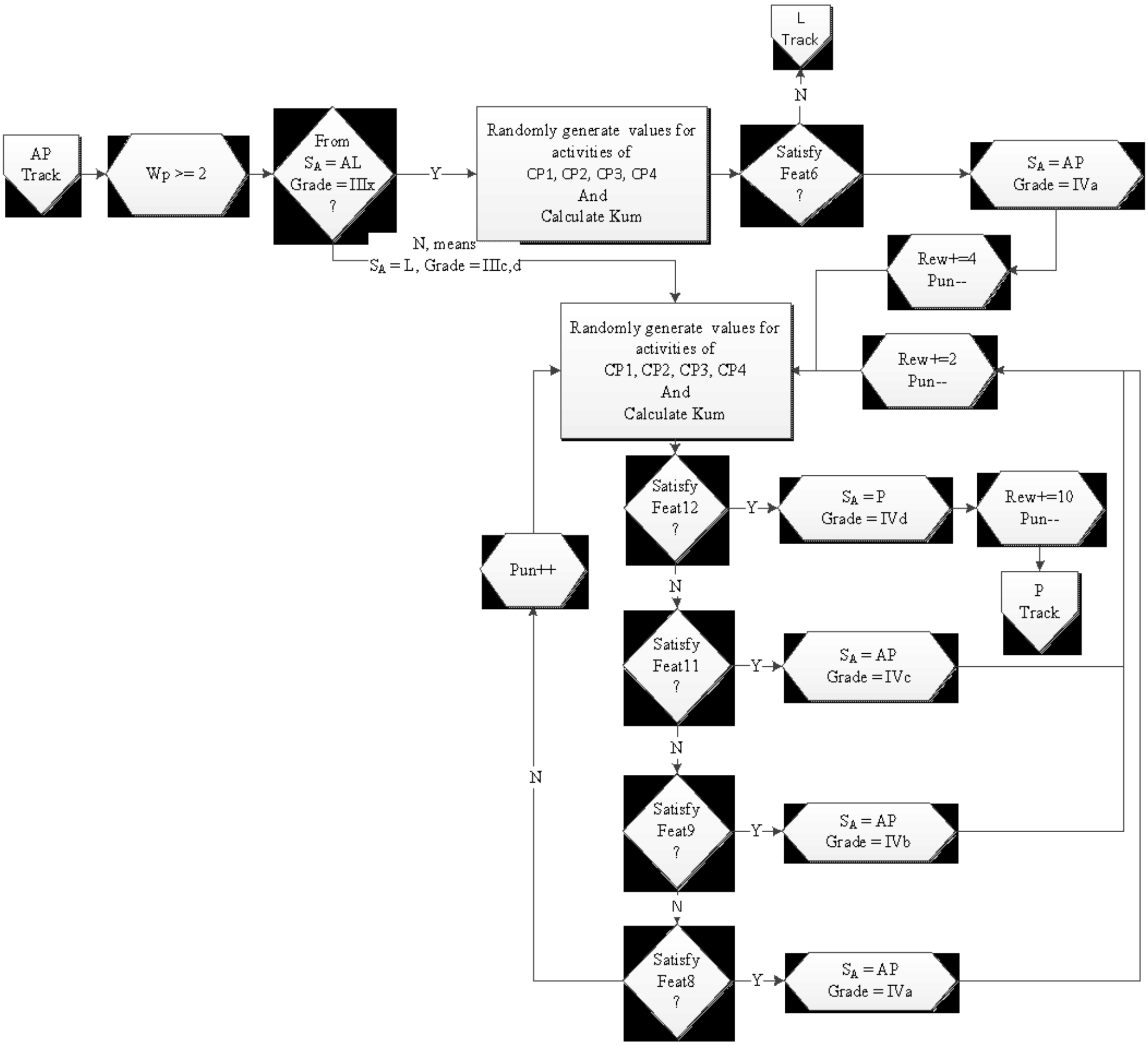

Fig. 9. The flowchart of the Associate Professor track.

The Associate Professor track (Fig. 9) explains some ways that can be followed in order to reach AP with different grades. E can start from AL or AP. If the current FD is AL (with grade IIIx, x is in {a, b, c, d}) and E desires to reach two next FDs i.e. AP (IVa), then E's features should satisfy Feat_6; however, if no Feat_6 is satisfied yet, then E can improve his/her feature set by following the L track. Otherwise, if E has already become an AP, then he/she can reach AP with higher grade IVb or IVc by satisfying Feat_9or Feat_(11)respectively. However, if for some years E is stuck in AP (with any grade) then certain punishment can be delivered to E. Conversely, if E's features are excellent then he/she has the opportunity to be a Professor (IVd) if Feat_(12)is satisfied. Reward for AP is also quite special i.e. two points, with an exceptional four points for those who jump two FDs.

The Professor track (Fig. 10) explains that someone who wants to be a professor should be working as an educator for at least 10 years. The track is rather like the AP track in that there is an opportunity for E, who is an L (IIIc or IIId), to jump two FDs to Professor, with a special additional 10 points (Rew+ = 10), if the feature set meets Feat10 criteria. However, if E starts from AP (IVa or IVb), then E can continue as a Professor with Grade IVc, IVd, or IVe if E's features satisfy $Feat_{10}$, $Feat_{11}$, and $Feat_{13}$, respectively, with additional four points (Rew+ = 4). Like an AP, a professor who is idle at a grade without any improvement for a certain period should be evaluated with certain punishment. On the other hand, Professor (IVe) is the highest FD in the overall educator's career journey. Thus, E has accomplished the mission as a professional educator if it is reached and therefore the simulation ends.

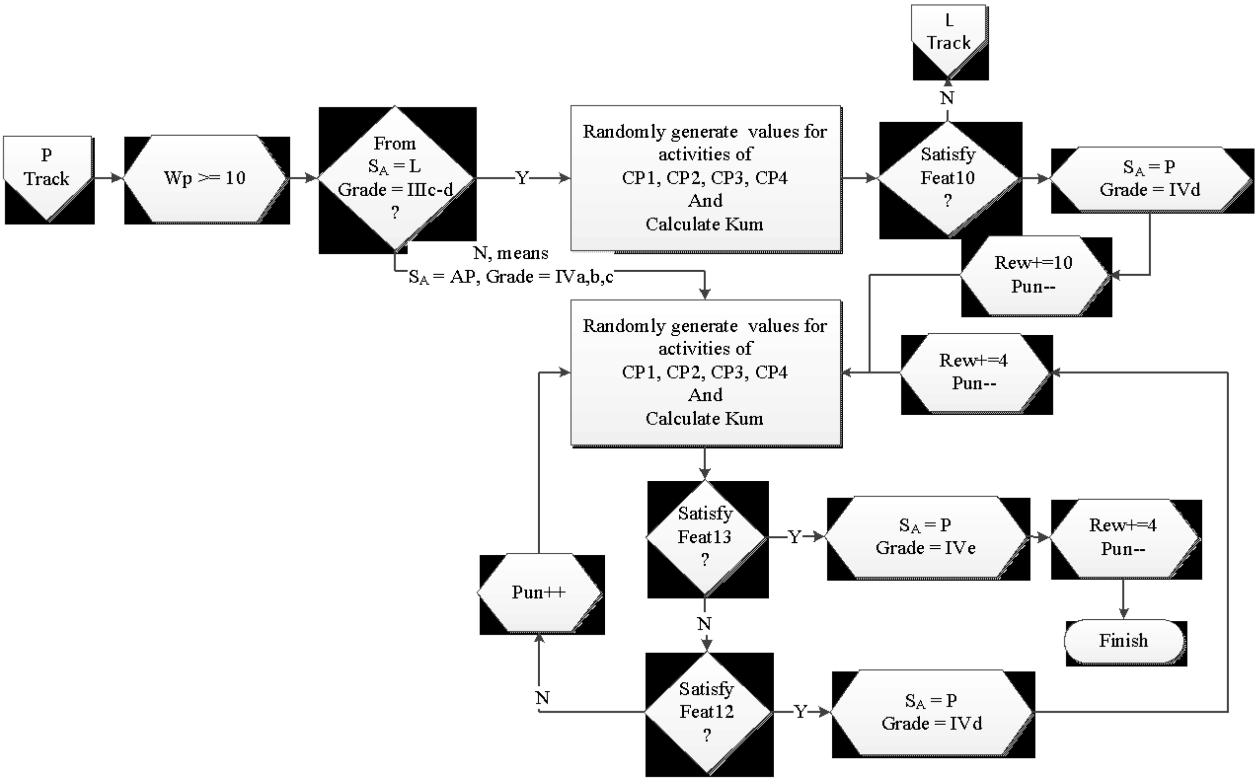

Fig. 10. The flowchart of the Professor track.

IV. Results and Discussion

A. Simulation Results

As shown in Fig. 11, three variables, constraint, Wp, and Ed, are prompted (indicated by a question mark), and the user can manually enter the values. In addition, the *Req* column (or required *totalKum)* initially always contains 100 points, which is the credit point of a bachelor's degree. It is assumed that all educators start their careers as teachers (T). The "Yours" column is the totalKum the educator obtained thus far, while $Kum = CP_1 + CP_2 + CP_3 + CP_4$. FD and Gr explain the FD and respective grade, while Rew and Pun express the reward and punishment points.

The first simulation is performed with the assumption that the career promotion is running properly. The initial values for these variables are cons = N, Wp = 1y, and Ed = master, and after they are supplied, the program randomly generates values for CP1– CP4. A Master's degree is equivalent to 50 credit points and this point is added to CP1. The complete results of the simulation are shown in Fig. 12, which demonstrates how E initially reaches AL (IIIb) by obtaining 172.56 points, higher than the required 150 points. The reward point starts from zero and increments with a number described in the flowchart, and there is no punishment given because E is never stuck on an FD and respective grade for a long time. E accomplishes all missions in 15 years. Column "cons" contains the constraint mark, which in this case is N as no constraint is applied. In addition to the master's degree, the doctoral degree is equal to 50 credit points, and this value is added to CP_1. This rule is applied to all simulations.

Start

cons	Wp	Ed	Cp1	Cp2	Cp3	Cp4	Kum	FD	Gr	Req	Yours	Rew	Pun
										100		0	0
?	?	?											

Fig. 11. Manual input of variables during the simulation.

Start

cons	Wp	Ed	CP1	CP2	CP3	CP4	Kum	FD	Gr	Req	Yours	Rew	Pun
										100		0	0
N	1	M	59.9	7.25	2.98	2.43	72.56	AL	IIIb	150	172.56	1	0
N	2	M	72.95	17.9	4.8	3.4	99.05	L	IIIc	200	249.05	2	0
N	2	M	110.8	39.7	5.5	2.5	158.5	L	IIId	300	358.5	3	0
N	2	M	113.8	43.8	4.7	3.5	165.8	AP	Iva	400	465.8	5	0
N	2	D	160.9	45.4	3.2	3.6	213.1	AP	IVb	550	613.1	7	0
N	2	D	157.33	40.5	2.8	5.5	206.13	AP	IVc	700	756.13	9	0
N	2	D	164.52	65.2	5.2	8.6	243.52	P	IVd	850	943.52	13	0
N	2	D	162.14	80.5	5.9	7.5	256.04	P	IVe	1050	1106.04	17	0

Finish

Fig. 12. Results of the first simulation.

Start

cons	Wp	Ed	CP1	CP2	CP3	CP4	Kum	FD	Gr	Req	Yours	Rew	Pun
										100		0	0
N	1	M	68.53	9.89	2.75	2.5	83.67	AL	IIIb	150	183.67	1	0
N	2	M	73.45	18.95	2.7	2.8	97.9	L	IIIc	200	247.9	2	0
N	2	M	115.8	11.3	2.2	3.1	132.4	L	IIId	300	332.4	3	0
D	2	M	*56.34*	*15.49*	*2.4*	*3.45*	*77.68*	*L*	*IIId*	*300*	*377.68*	*2*	*1*
N	1	M	116.87	44.65	4.1	5.65	171.27	AP	IVa	400	471.27	4	0
N	3	D	114.4	45.83	3.33	4.6	168.16	AP	IVb	550	568.16	6	0
N	3	D	125.12	52.5	4.52	7.84	189.98	AP	IVc	700	739.98	8	0
N	2	D	161.2	53.42	2.73	2.86	220.21	P	IVd	850	920.21	12	0
N	2	D	213.14	64.98	2.99	3.42	284.53	P	IVe	1050	1134.53	16	0

Finish

Fig. 13. Results of the second simulation.

In the second simulation (Fig. 13), a constraint [cons = D (delay)] is given between L and AP. Thus, the educator cannot easily reach AP (IVa) from L (IIId). After the constraint is given, the program randomly generates low CP_1 and CP2 and their value cannot satisfy $Feat_8$, hence the *totalKum* is smaller than 400 credit points. At this moment, E is stuck at state L (IIId) for 4 years; thus, the reward point is also decremented by one, whereas the punishment is incremented by one. On the other hand, CP_3 and CP_4 values are not the main activities because according to Table III, Es can continue to the next state even if these values remain zero. However, as they are part of 3D-HEI, Es are demanded to have at least one activity per semester in community engagement and additional activity aspects. By the simulation, the most important activities are those in the first and second aspects of 3D-HEIs, so E should not focus only on the third and fourth ones. The game finishes after 18 years in this simulation and it can be a good reference for the lecturers to plan their career milestones year by year.

The third simulation is a contrast of the second one as the constraint is set to cons = J (jump), which means that E has some features that allow E to jump two next FDs. In this simulation, the constraint is applied between AL (IIIb) and AP (IVa). Similarly, after cons, Wp and Ed values are setups, and the program randomly generates some values that the features satisfy *Feat8*; thus, the career leap is likely to occur. The results of the simulation are given in Fig. 14.

In line 2, the reviewer intentionally sets *Ed* to master, and the total *Wp* is set to 4y (3 years + 1 from the previous state) to see how the program generates random values that can satisfy career jumping. This results in *totalKum* = 424.75, which exceeds the minimum 400 *totalKum* required to go to AP (IVa). As the reward, four points are added to the current reward according to the flowchart. In this case, an educator can be a Professor (IVd) in only 11 years, which obviously can occur only for excellent people, particularly in research activities.

Start

cons	Wp	Ed	CP1	CP2	CP3	CP4	Kum	FD	Gr	Req	Yours	Rew	Pun
										100			
N	1	M	56.53	6.89	2.98	2.43	68.83	AL	IIIb	150	168.83	1	0
J	3	M	178.7	82.35	5.2	8.5	274.75	AP	IVa	400	424.75	5	0
N	2	D	160.4	47.28	4.9	5.8	218.38	AP	IVb	550	618.38	7	0
N	3	D	170.12	50.25	3.75	4.45	228.57	AP	IVc	700	778.57	9	0
N	2	D	165.2	65.27	2.95	5.84	239.26	P	IVd	850	939.26	13	0
N	2	D	213.14	80.68	4.75	6.45	305.02	P	IVe	1050	1155.02	17	0

Finish

Fig. 14. Results of the third simulation.

Other cases, such as the jumping from a Lecturer (IIIc/d) to Professor (IVc) or the delayed promotions at a certain FD, are not further discussed as their career milestones can be understood easily from the given cases. Nonetheless, career journeys, such as these three given instances, have been witnessed correctly by the appointed ECS reviewer team.

Adapting an approach proposed by Cardador and Northcraft *et al.* [1] the Mealy machine can give the educator more visible and comparable information about the performance they achieved thus far. The comparison here is referred to as inputs, outputs, and achievements obtained between FDs. Another advantage of using the Mealy machine is that the career transition can be described visually as given in Fig. 15, which can be used as a performance progress indicator of the educator. Fig. 15(a), (b), and (c) represent the result of the first, second, and third simulations, respectively. Fig. 15(c), for example, illustrates how an educator E jumped over the Lecturer state by satisfying $Feat_6$, whereas Fig. 15(b) describes how E was stuck on Lecturer (IIId). In the affective aspect, the proposed Mealy machine can also represent some game components such as levels (the states or FDs) and the points through grade, reward, and punishment systems.

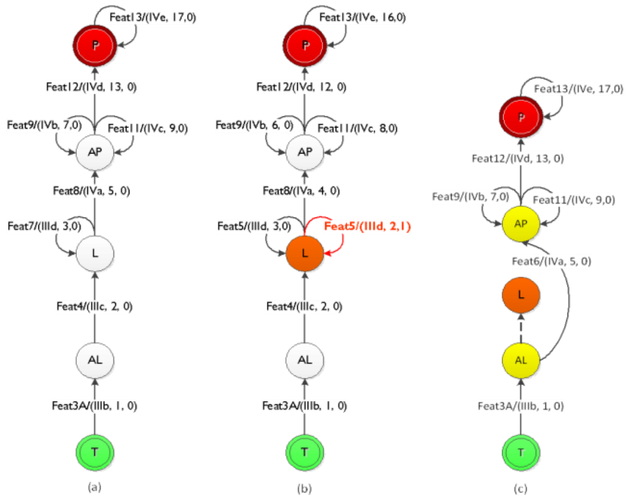

Fig. 15. Career transition with (a) no constraint, (b) delayed constraint, and (c) jumping constrain.

V. Conclusion

This study proposes MDA-ECS, a new gamification model for ECS currently in use in Indonesian HEIs. Then, as the mechanic for the proposed gamification model, a 5-tuple Mealy machine is proposed, which consists of four elements: (career) states, start states, inputs, outputs, and transitions. Four FDs, namely AL, lecturer, AP, and professor, become the machine states that represent the mission that the educators set out to accomplish in their career journey. Credit points from four aspects of 3D-HEI collected by the educator are the machine's inputs, while FD grade, reward, and punishment are the machine's outputs, and thus the gamification part. Furthermore, 15 transition types are defined for the transition from the current to the next FD. The simulation results show that the Mealy machine meets the informational and affective aspects of the ECS regulation in Indonesian HEIs. Because this study is developing a new gamification model, we hope this paper will assist gamification designers in developing better gamification models for ECS, which may differ from university to university.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Related conceptualizations Defining and designing automata: I.D.M., T.M.A.; Methodology: I.D.M., T.M.A., S.M., E.P.; Implementing design into programming languages including automated testing: I.D.M., T.M.A.; Contributing to information on the Higher Education system in Indonesia including the lecturer career system: I.D.M., T.M.A., S.M., E.P., all authors had approved the final version.

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