Gamifying Experiential Learning Theory

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Abstract. Motivating student learning and enhancing student learning performance can be done by gamifying existing learning systems via adding gaming elements to the systems, or by developing dedicated games for learning purposes. However, it is both costly and challenging to develop such systems, since it requires to fill the gap in cognition and knowledge between educators and game designers before they can properly transfer learning theories to game mechanics and elements for gamification or serious game implementation. This paper proposes to gamify experiential learning theory by mapping it to the positive and negative feedback mechanisms of the internal economy of game machinations. Hence, developing serious games becomes easier, since the effort of getting mutual understanding between educators and game designers can be effectively reduced. Our study assesses the proposed model by obtaining the experts' (game designers/educators) perceptions of the model mapping, and its usefulness and usability, via an online questionnaire. A total of 23 participants answered the questionnaire by stating that our model was useful and could suitably mapped the learning theory to game design. We also present a field-based learning game as an application of our proposed model.

Keywords: Game-based learning, Experiential learning theory, Gamification.

1 Introduction

Gamification is defined as using or applying game elements to a context unrelated to playing [8]. It can be applied to encourage collaboration [18], involve employees in tasks [27], or even increase customers' loyalty via stamp cards [17]. However, gamification in teaching and learning defines a systematic process rather than one task, such as collecting badges, and aims to solve a particular learning problem through increased engagement and motivation [24].

Game-based learning (GBL) is more comprehensive with regard to the game elements applied (points, badges, narrative, etc.) in addition to utilising game mechanics (physics, internal economy, progression, etc.). GBL can be seen as teaching and learning real-world knowledge and skills within a game environment, with the aim of transferring learning to real-world situations, while gamification in learning creates a gamified real-world environment for solving real-world problems. The concept of gamification is applied to learning via gamifying lessons or field trips, while it can also be utilised to gamify learning theories to design and instruct the learning process. Kolb's Experiential Learning Theory (ELT) [20] is a well-known theory considers experience to be the central source of learning and development. It consists of four stages: concrete experience (CE) involves perceiving new knowledge by experiencing the concrete through sensing real situations; reflective observation (RO) focuses on watching and reflecting on the learner's own experiences or those of others; abstract conceptualisation (AC) is about analysing, synthesising, or planning via a representative presentation; and active experiment (AE) involves doing things. These four stages have to be completed in a cycle starting from any stage, with the possibility of repeating stages as needed. The theory emphasises the importance of experience in the learning process, such as in laboratory sessions and fieldwork.

Our main contribution is gamifying ELT by mapping it to the internal economy of game machinations [3]. The main components of the internal economy mechanic (resources, internal mechanic, feedback loops) are defined for each stage of ELT, forming building blocks of experiential learning that can facilitate GBL systems development.

The remainder of the paper is structured as follows. Firstly, a review of related work regarding GBL, and modelling ELT, is presented. The next section discusses two essential concepts of modelling ELT (internal economy mechanic and game machi-nations). This is followed by describing the ELT model and presenting an implementation of a FBL game. Thereafter, our initial study is depicted, and the final section provides a conclusion and discusses future work.

2 Related Work

GBL is the procedure and practice of learning utilising games. GBL can utilise digital or non-digital games. GBL prompts learning , facilitates evaluation [29], and develops skills [7]. In games, players are actively motivated to overcome their losses and to pursue more tasks and challenges. The drive and elevated levels of motivation are what educators desire for their students to progress in the learning achievement. Any learning process that uses GBL as a tool of education benefits from engagement and motivation. However, reducing the GBL design to few game elements would limit the learning effect [21]. The limitation of GBL can be caused by a lack of theoretical foundations. Nevertheless, the literature shows the utilisation of many learning theories [12, 30] in designing GBL, such as ELT [16]. Designing GBL to provide experiential learning would produce a more effective learning experience [19]. Broadly speaking, GBL can be achieved in two ways: educators/game designers either collaborate to build games or use commercial off-the-shelf games; each way has its advantages and disadvantages. It is important to design GBL carefully to provide more than just motivation, by applying learning theories and creating a balance between learning theories on the one hand, and game elements and mechanics on the other. We propose a model to gamify ELT, in order to help game designers/educators to create a balanced GBL that increases student motivation and improves their learning performance.

Various academic disciplines employ ELT, such as chemical engineering [1], tourism [14], computer science [32], and FBL [5]. There is a tendency to apply ELT for instructing or designing GBL without following specific guidance or models [10, 11, 13, 22, 26, 28, 31]. Conceptual and theoretical models are needed to guide the process of operating and designing GBL [4]. However, there have been a few at-tempts to model ELT to design GBL [16, 25]. For example, the experiential gaming model [16] aims to integrate ELT with game design and flow theory. The model highlights the significance of clear goals, balancing the player's ability and the challenges provided, and delivering im-mediate feedback. It consists of experience and ideation loops in addition to a challenge depository. The metaphor of the heart is presented to supply challenges based on learning objectives. The model connects ELT to game design, yet it ignores two important elements of both GBL and ELT: interaction and assessment. In addition, the model does not focus on concrete guidance, but provides abstract principles. [25] presents another example of a framework for using ELT to develop GBL. The framework links each stage of the ELT cycle to one game element, such as linking Gameplay to CE, to provide engagement and linking feedback to RO and create an opportunity for reflection. The framework ignores the im-portance of game mechanics and is limited to a few game elements in addition to skipping guidance.

Some studies applied general models to design experiential learning in GBL [15, 23]. A final thought on gamifying ELT is presented in the literature by utilising one or two game design concepts, such as role-playing/narrative [14], and engagement [6].

3 Game Mechanics

Games in general build on rules of play, and digital games consider rules as mechanics that govern the relationships between gameplay components. There are five types of game mechanics: progression, physics, internal economy, tactical manoeuvring, and social interaction [2]. Usually, several game mechanics are combined with one core mechanic which has the most impact on the game's aspects. However, the internal economy is the basic mechanic and the most involved in de-signing digital games.

The strength of the internal economy comes from handling the flow and transaction of game elements that are considered resources (coins and lives) in quantifiable amounts. A general definition of an economy is a system that produces, consumes, and trades resources in measurable amounts; it is similar to a real-life economy. The internal economy manipulates many kinds of resources which can differ from what people are used to in real life, such as health and stars. Three components structure the internal economy, namely resources, internal mechanics, and feedback loops.

Any object that can be quantified numerically in a game is a resource, such as enemies and ammunition. Players can control things by gathering, destroying, or producing different objects which formulate resources. Some resources need to be stored in a container called an entity, such as storing collected gold in an entity (gold box). Resources flow from one entity to another according to four internal mechanics: source, drain, converter, and trader. The source mechanic produces new resources, such as creating new dots in the Pac-Man game. The production of the source could be based on a condition, triggered by an event or automatically based on a time interval. Also, sources have a production rate, which can be fixed or variable depending on the time or amount of another resource. The condition, automation, and changing rate are concepts that apply to all internal mechanics. The drain mechanic consumes resources, and they are removed permanently. On the other hand, the converter changes one type of resource to another, such as converting flour to bread. The trader mechanic exchanges two different resources between two different entities according to a specific rate. For example, a player can trade a shield to get a more powerful gun.

When a resource that results from a mechanic feeds back and affects the same mechanic at a later time in the game, this is called a feedback loop. For example, taking one piece of the opponent in a chess game will make it easier to take the next piece. A positive feedback loop applies when the effect of the loop becomes stronger in each loop. However, the positive feedback loop can cause deadlock when the production of two resources is mutually dependent on each. For example, when building a stonecutter's hut in Settlers III, the stonecutter's hut produces stone and at the same time the player needs the stone to build the stonecutter's hut. The game starts with some stones, but if a player uses them for other tasks before building the stonecutter's hut, then they could end up without enough stones to build the hut. A positive feedback loop helps the player to win quickly when an important difference is achieved in skill or effort. On the other hand, a negative feedback loop stabilises the production mechanism, such as in a car racing game, where the positions of players' cars appear to be attached to each other by a rubber band. No car will get too far ahead of the others or too far behind the rest. This can be balanced by powering up the slowest car with random power or increasing the difficulty of the leader car with blocks. It will increase excitement by creating chances for other players to take the lead.

The game machinations framework [3] is a tool to envision game mechanics. Our work utilises the game machinations to present the gamification of ELT aspects to an internal economy, through mapping between the ELT stages and the components of the internal economy mechanic (defining flows to form an ELT cycle as the components can be manipulated to reach the desired settings of GBL). The symbols of game machinations are a way of facilitating and supporting the modelling of the internal economy in a graphical representation. For example, entities that store resources are represented by an open circle (pool), while resources are symbolised by small, coloured circles (coins) or as numbers. Another example is the source mechanic, which is represented by a triangle pointing upwards, and a solid arrow, which represents the flow of resources from a source to a pool entity.

4 Gamification of Experiential Learning

The internal economy is used to gamify ELT aspects to link them to game design. For each stage of ELT, resources are defined along with a suitable internal mechanic and feedback loop when needed. These three components transfer the theory into the game's internal economy, as shown in Fig. 1. It is a model of the learner's progress in reaching different stages of the ELT cycle while performing learning tasks. By completing a stage, the knowledge/skill of player will be expanded to show progression in performance. Four resources are defined, each of which represents a different level of achievement and is associated with a specific stage of the ELT cycle. Internal mechanics (source and converter) are used to show the flow and transaction of these resources from one stage to the next. The cycle can be repeated via a feedback loop to improve performance in the next cycle by acting on the learning feedback, as shown in Fig. 2.

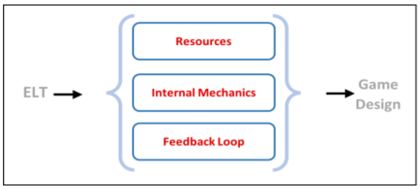

Fig. 1. Modelling ELT as an internal economy

The first stage is CE, and it is mapped to a simple internal mechanic where the player grasps knowledge, and it is conceptualised as the interactive source *Task* to achieve a task (Fig. 2 - (CE)). The difficulty of task is demonstrated as a gate with the player skill symbol and the probability of successfully producing *level1* as *p1*. For example, *p1* could be a fifty % chance of accomplishing the task successfully according to the ability level and making an observation resource to be stored in the *level1* pool. *Level1* is defined as observation, because in the first stage the player is expected to have a new experience and develop knowledge by observing the learning environment.

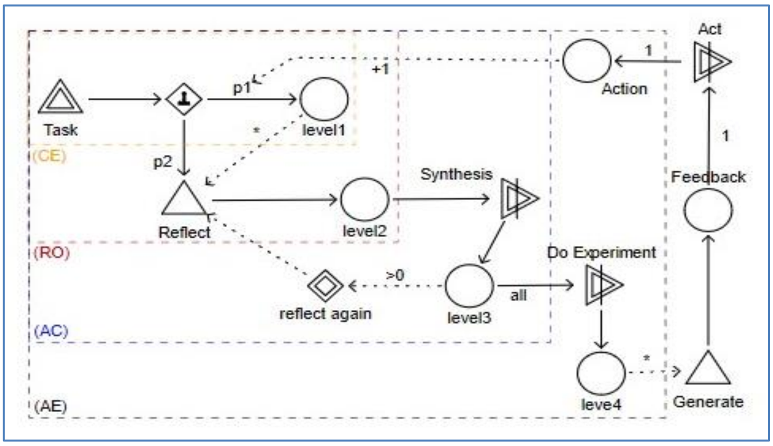

Fig. 2. Gamified ELT model

RO is a mental activity, which can be inspired by tasks such as encouraging conversation. In Fig. 2 - (RO), a source represents reflection, *Reflect*, it can be generated in one of two different scenarios: whether or not the player completed the task in the first stage successfully. In the first scenario, as a resource is stored in the *level1* pool, the reflection will be triggered by the trigger state connection that links *level1* to *Reflect*, as it is expected to reflect when the player has successfully accomplished the task. In the second scenario, which applies if the task could not be completed, the gate guarantees the redistribution of the player's experience to reflect by *p2*, where *p2* represents the probability of the player's ability to reflect when the task is not completed successfully, showing that he/she still learned something, even from mistakes. The player should produce resources of reflection, which are stored in the *level2* pool by the end of the second stage.

The third stage (AC) can be done via a loop of synthesising and reflecting again until the final result is formed (Fig. 2 - (AC)). The loop begins from the interactive converter *Synthesis* by transferring resources in *level2* to synthesise and plan and then save them in the *level3* pool. Storing resources in the *level3* pool will activate the interactive gate (*reflect again*) by the activator state connection and the condition specified on the label as (0>). At this point, the player has the choice to click on the *reflect again* gate or move on to the final stage. If the player chooses to click on the gate, the source *Reflect* will be triggered to generate more resources to be stored in the *Level2* pool and these then can be synthesised again. The final stage (AE) is conceptualized with the interactive *Do Experiment* converter, which represents the action of the player undergoing a new experience based on the synthesised ideas and plan from the previous stage (*Level3*). This will result in producing new knowledge stored in the *Level4* pool after a full ELT learning cycle.

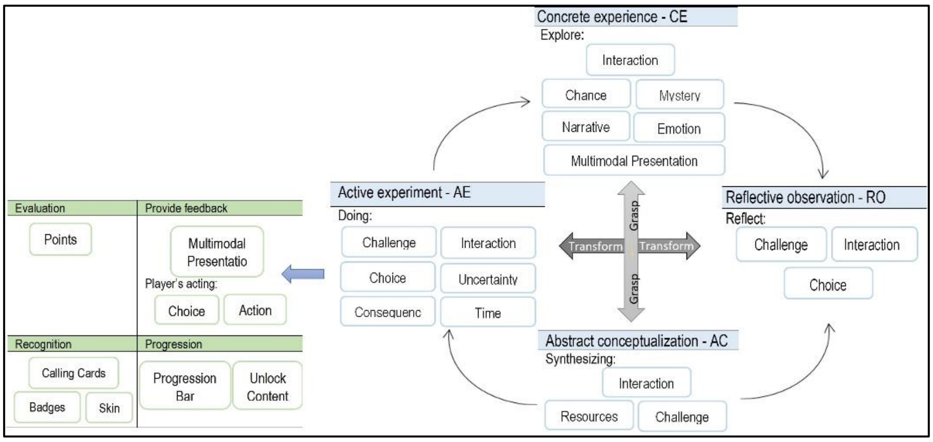

Fig. 3. Game elements matching scheme

Before starting a new cycle, the player is demanding feedback as a result of evaluation. The source *Generator* in Fig. 2 symbolises feedback provision, which will be triggered automatically by storing resources in *Level4*. The generated feedback will be stored in the *Feedback* pool. The player has to act on the feedback provided by clicking on the interactive converter *Act*, which will produce Action resources showing the player utilised the feedback to improve or fix something in the task performance.

Working through the whole cycle and acting on the feedback will improve the knowledge/skill of player, which will raise the probability of completing the task successfully in the following cycle. This is achieved by a label modifier with (+), where the percentage will be increased by some value as decided by the game designer/educator automatically each time resources are stored in the Action pool. Each stage of the ELT cycle forms a building block that can be facilitated in the process of designing

GBL. The following step enhances the gamification process by linking the internal economy representation of stages into specific game elements, as shown in Fig. 3. Educa-tors/game designers can utilise all the elements into the matching scheme or select what fits the learning objectives. More explanation is provided in the implementation section.

5 Implementation of a Field-Based Learning Game

A prototype is designed and implemented based on the gamified ELT model to provide experiential learning via a virtual field trip game (VFTG) for secondary school students. It is called Island of Volcanoes and set in Bali Island which includes three volcanoes: Mount Agung, Mount Batur, and Mount Bratan. The learning content was chosen from Key Stage 3 of the most recent National Curriculum in England for Geography - natural hazards (volcanoes) along with geographical skills (aerial view (Fig. 4 – (b)) and geographical information). It is an experience of surviving on the island by observing, collecting data, planning, and then acting. The resources of each stage are defined, along with their flows as an internal economy by the required internal mechanics and feedback loops. The components of gamified ELT modelling are summarised in Table 1, followed by detailed explanations.

Table 1. The components of gamified ELT modelling.

Stage	Required Resources	Produced Resource	Internal Mechanic	Feedback Loop
CE	Previous Knowledge	Level1 – observing volcanoes on the island.	Creating (source)	Positive feedback loop: the more the player puts out fires, the more he/she observes the island.
RO	Level1	Level2 – Collecting information about observed volcanoes.	Creating (source)	Positive feedback loop: if the player finds one piece of information, the rest of the required data can be found easily.
AC	Level2	Level3 - Hypothesising and planning from observations and collected data. + Level2	Converting (converter)	Possible negative feedback loop, where it will get harder to hypothesise and plan with the appearance of new signs of natural hazards.
AE	Level3	Level4 – Acting on the plan.	Creating (source)	Possible negative feedback loop, where the task becomes harder for faster players.

In the CE stage, players will be motivated to explore and observe the virtual field environment (VFE) by collecting gems, a commonly found mineral in volcano lava, to fill the gun’s tank with water and be able to put out the fires to save the island (Fig. 4 – (a)). The gems/fires are scattered all over the VFE, with the aim of creating level1 resource (observations of Bali). The player is expected to identify the number of volcanoes on the island as a result of observation. The design includes a positive feed-back loop, where the more the player puts out the fires with the water gun, the more he/she has the chance to walk around the island and observe the environmental terrain. A second task is required in this stage, which is recalling previous knowledge (the structure of a volcano) by labelling its parts in a diagram.

In the RO stage, the player will be encouraged to reflect on the observations from the first stage, and level1 should be converted to level2 (reflecting) resource. The reflection is performed by finding geographical information about the observed environmental terrain, which is supposed to include observing volcanoes to gain further understanding of the situation on the island. The player has to collect data about a specific volcano on the island (name, country, type, status) and record them in a table inside the game (Fig. 4 – (a)). The player searches a learning resource made available for access via a button on the user interface (UI): a monitoring web page displays a volcanic map of Bali along with information. A positive feedback loop is designed so that, if the player finds one piece of information about the observed volcano, he/she can find the next required data.

In the AC stage, the player will experience one of two different scenarios: scenario1 (releasing gas earthquake) or scenario2 (releasing ash/lava and seeing some animals running). Thus, the player will be prompted to synthesise and hypothesise about the presented scenario (the natural signs) along with the observations (*level1*) and the collected data (*level2*). The result forms level3 resource by defining the situation on the island and classifying the natural signs according to two levels of danger. The feedback loop in this stage is optional and the player can choose to reflect again after synthesising until the final result is formed. A negative feedback loop could be de-signed to achieve a balance, whereby it becomes more difficult for the player to hypothesise and plan after forming the initial result as new signs of natural hazards emerge.

Fig. 4. (a) Gathering information, (b) collecting gems, putting out fires, and aerial view

In the AE stage, the player will be forced to act on the synthesised classification (*Level3*) from the third stage in connection with the resources produced by previous tasks (*Level1* and *Level2*). The player has to make a decision and act on it (doing), escaping the natural hazard by selecting the best vehicle and buying a car, or running to a safe area on the island (scenario1), or finding a boat in order to leave the island (senario2) based on the level of danger. A negative feedback loop could be designed where the task of escaping becomes more difficult for players who have completed the previous tasks in a shorter amount of time: barriers are added, impeding their route to a vehicle. CE is the most frequent entrance stage of the ELT cycle [9], so the prototype is designed to start with it. However, the model defines the building blocks of each stage, meaning that the building blocks can be rearranged to start the ELT cycle from any stage based on the player's learning style.

Some game elements were selected from Fig. 3 to enhance the gamification of the ELT stages. The interaction is utilised to design the tasks of all the ELT stages where the interaction between the player and the environment results in exploring and collecting data. For the CE stage, multimodal presentation is employed through different forms of learning materials (text and video). The narrative is introduced in the CE stage by an NPC (Red Dragon) to create an engaging context with a feeling of danger related to the volcano's eruption and the urge to survive. In the RO stage, the player is encouraged to reflect on the observation of the existent volcanoes and challenged to learn more about their status (by collecting data). The control of choice gives them the opportunity to correct any incorrect collected data. In the AC stage, interaction is applied by sending signs to the player from the environment and challenging them to understand the surroundings in order to plan an escape and survive. In the AE stage, a challenge is employed where the player has to survive the danger of a volcano with-in a certain amount of time. An element of choice is provided by selecting the best method (boat or car) to escape the danger. If the wrong method to escape is selected, there will be a consequence and the game will continue, with uncertainty about what will happen.

The assessment and feedback can be provided after the final stage or after each stage. The applied game elements are the awarding of points for assessment and badges for recognition. Feedback is applied according to a multimodal presentation - colour and motion. A control of choice is provided to take action to find the correct answers and is given two chances for two learning tasks (labelling the volcano's parts and collecting data). The progression step is designed as unlocking content (new tasks and materials).

The prototype was implemented via the Unity Game Engine. A heightmap of Bali was converted to a terrain. Basic elements of the environment were added, such as water, skybox, the lakes of volcanoes and the cycle of day and night. After registration and selecting an identity, the player is provided with three options: Play, Help, and Quit. The player can display the list of quests (learning tasks) by clicking a button in the top left corner of UI, as a way to interweave the learning tasks into the game-play. A green check will appear next to each quest completed by the player. Also, some of the learning tasks and rules are hidden and introduced to the player by the Red Dragon implicitly as a part of the story, such as telling the player about the value of blue gems and the survival kit items. In addition, some learning materials intervene in the story.

Assessment and feedback are provided after completing the tasks of the CE and RO stages. A check button is provided to give the player a choice to ask and receive feedback. A flying bird appears randomly over one of the three volcanoes after the player collects at least one item of the survival kit. The player is expected to observe the flying bird and explore the area near that volcano, which leads to displaying a table to collect the geographical information. The player will gain coins for correct collected data from RO task. A timer is displayed after 30 seconds of classifying the level of danger to create some pressure to complete the quest within that period. The player should use coins gained from the previous task to pay for a vehicle. The purchased vehicle will appear near the seaside and the player can ride it. A gold badge is awarded when the player selects the correct vehicle based on the presented scenario. If the player selects the wrong vehicle and cannot escape the eruption by leaving the island, he/she can die from the lava or ash. However, the player may select the wrong vehicle but not die, in which case a silver badge is awarded.

6 Evaluation

A preliminary evaluation of the gamified ELT model was designed to seek the experts' opinions of the model. A questionnaire was designed to measure the mapping, usefulness, and usability of the gamified ELT. The questionnaire gathered data about demographic information (sex and location), and professional experience (occupation and type of learning institution). Three statements are asked about the mapping, two statements about usefulness, and ten statements are about the usability of the model, which was a modified version of the System Usability Scale (SUS). A five-point Likert scale, ranges from strongly agree=5 to strongly disagree=1, is applied to answer the statements. Also, three questions are asked about the overall opinion of the model and suggestions.

Twenty-three participants answered the questionnaire. The participants included 7 females (30.4%) and 16 males (69.6%), and all the participants were from the UK. There were ten educators (43.5%), seven game designers (30.4%) and six participants who defined themselves as both (23.1%). Regarding learning institution, five participants work in schools (21.1%) and 18 work at universities (78.3%). Cronbach's alpha was calculated: mapping (α= 0.824), usefulness (α= 0.891), and usability (α= 0.869). The results indicate good internal consistency and reliability for the statements of each scale. All statements of the mapping scale have the same median (4) and the IQR values range from 0 to 2, which indicates that most participants expressed agreement regarding the mapping between the ELT stages and the internal economy. Regarding usefulness, the median for both statements is 4 and IQR values are 3 and 2, which reveals an agreement trend. This suggests that the participants found the model useful. The SUS scores are computed in a combined way to generate a one usability score between 0 and 100. 68.043 is he average usability score, which indicates that the usability performance is better than average.

The participants answered a question regarding the possibility of considering using the model in their future research. The highest percentage (39.13%) of participants indicated that they would definitely use it, followed by 30.43% who would probably use it, and 26.09% who would probably not use it. Only 4.35% indicated that they would definitely not use it and the common reason stated in an open-ended question is that they do not do research in this area, while one participant expressed an intention to use the model to evaluate off-shelf experimental learning games. Another open-ended question asked about any concepts missing from the model and answers included skills and more explanation about assessment and feedback.

7 Conclusion and future work

Designing GBL requires a huge effort of collaboration from educators and game designers to successfully implement the system. However, it is an expensive process, even to develop one GBL, since lots of effort is spent on identifying mutual understanding in GBL among the educators and game designers, who have a significant gap in cognition and knowledge due to the difference in their expertise. Gamifying learning theories, such as ELT, bridge the distance between the two fields and facilitate the process of design GBL. This study presented a gamified ELT model by mapping the stages of ELT into the internal economy mechanic. The mapping process defines the main components of the internal economy mechanic (resources, internal mechanic, and feedback loop) of each stage and shows the flow and transaction of resources from one stage to the next as the player progresses in reaching different stages of the ELT cycle while performing learning tasks. Future work will involve developing the model by gamifying more learning theories (social learning theories, peer assessment, high-order skills) and connecting them to ELT to enhance the design of GBL.

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