Enhanced Knowledge and Engagement of Students Through the Gamification Concept of Game Elements

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Abstract—The idea of Gamification is very popular for applying the gaming concept theory in various fields. Nowhere else is this more important than in education. Considering the careful build-up and implementation of game-elements could improve academic performance outcome and student motivation. However, Gamification could require much more time to be designed and applied to education related activities and it also comes with significant operating and design cost to provide highly engaging activities for students. One of the main problems in designing Gamification is the question: "which game elements should be applied to student activities?". Moreover one must make sure that it has great impact on students' performance in terms of their education related performance. Hence, in this research, we focused on studying the impact of each element in order to investigate the behavioral outcome of game elements in educational environments through the concept of knowledge and game-based learning from the Gamification concept. In our experiment, we examined the impact of each game element on senior high school students based on the basic elements of Gamification such as Leaderboard, Cooperative and Awarding badges. In addition, we studied the effect of the game-based learning application called Aqua Republica from UNEP and DHI centers with partner of Thailand. The experiment design compared two groups: the "Non-Gamified" and the "Gamified" groups participating in the game-based learning activity Aqua Republica. Academic indicators and numerical indicators were used to directly measure the effect and behavioral outcome of the use of game elements. Finally, the study suggested that leaderboards could improve the overall performance of students so it can be worth implementing it in classroom activities.

Keywords—Game based learning, knowledge management, Gamification, game elements, and knowledge sharing and water management.

1 Introduction

Over the past few years, Gamification has been applied to almost every field of business, health and education. Examples for Gamification used in healthcare are the applications QUENTIQ (Dacadoo) and Fitocracy where Gamification concept was applied in order to motivate players to exercise more effectively and to change their exercise

practices. For the area of education, the Khan Academy used the Gamification techniques in their Massive Open Online Courses. They have introduced elements of Gamification such as visual constellation level and learners looking similar to the RPG skill tree. For that reason, many company and startups proposed the idea of Gamification design in terms of software-as-a service (SaaS) solutions, and many organizations in all fields began to implement Gamification as a way to improve the user experience and to motivate people. There are many examples for such applications from public and private business management to human resources, healthcare, classrooms in education, innovation, boosting employee performance, crowdsourcing concept, cultural heritage, civic engagement and digital marketing. Nowadays, the Gamification market has been predicted to amount to over US$ 11 billion by 2020. In theory, Gamification has been defined as a process of facilitating motivation with affordances about the engagement of the participant, resulting in invoking further behavioral change and playful experiences. In addition, many multidisciplinary research studies tried to implement game elements as we mentioned before to analyze the participant's experimental outcomes related to Gamification. However, recent research of Gamification lacks studies focusing on the behavior and performance outcome of each game element defining which game elements should be selected to maximize the effect of the Gamification concept.

For this research, we studied specifically the main the characteristics for each game elements focusing on the effect on the students including Cooperative, Leaderboard and Awarding badges in terms of behavior outcomes. Our experiments were tested on the international competition called Aqua Republica, a collaboration and partnership with the UNEP-DHI center. This paper is organized as follows: Section 2 describes the related work of game elements of the Gamification concept and game-based learning of the water resources management application. Section 3 describes the methodology for studying the effect of game elements. Section 4 then compares the results of the two groups "Non-Gamified" and "Gamified. Section 5 presents conclusions and Future work.

2 Related Work

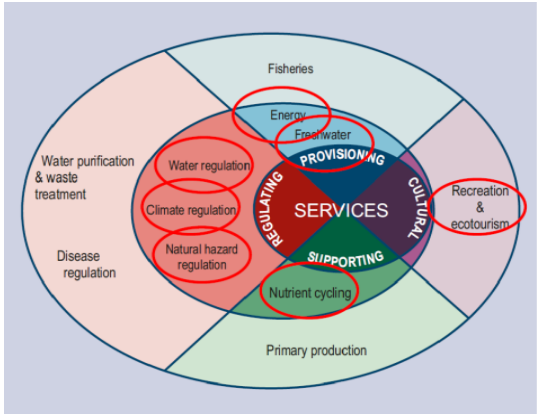
2.1 Gamification

Emerging from the entertainment game industry, the concept of Gamification is based on the idea of the fun factor of entertainment applied to stimulate the normal activity. However, the definition of the word Gamification is still not clearly given. Therefore, some researchers define the word Gamification as "the use of game elements and mechanics in non-game contexts [1]". In some research, the brief history of the original word "Gamification" is given in relation with similar concepts. In the field of education, some researchers applied the idea of Gamification to drive and boost the motivation of students with the purpose of engaging the students during boring classrooms to keep them focusing on the lesson [2][3]. In addition, in the practice of application under which the basic concept of game mechanics are adapted to the classroom,

students use game elements from entertaining games such as badges and virtual gifts/rewards which can stimulate student motivation both intrinsically and extrinsically in the classroom improving retention rates. Most of the practical applications using the Gamification concept implement the global leaderboard where participants' scores can be shown to all participants. [4] proposes the implementation of Awarding badges to the classroom called Badge Architectures for boosting the motivation of student. Similarly [5] implements the game element of leaderboard to rank the students under a reward systems with undergraduate courses with great impact on learning success in terms of statistical significance and positive effects.[13][14] focus on studying leaderboards and achievement systems showing that these strategies had an additional effect on user experience and user responses less reflective to real-world conversations. [6] showed that leaderboards can give opportunities to all participants moving both downward and upward in order to compete and compare their scores in terms of performance. Even the concept of game elements using the leaderboard may increase engagement and satisfaction and the sense of superiority [9][10][11][12] but they also suggest that leaderboards may have a negative reinforcing effect on low performance of students who give up easily or who are less competitive relative to others.

2.2 Game-based learning for integrated water resources management

It has been for a long time that the people around the world struggle with organizing and managing the water resources potentially useful for the society and for industrial, agricultural or recreational purposes. The DHI and UNEP-DHI Centre designed a game-based learning application called Aqua Republica [7]. The basic concept of Aqua Republica aims to promote and develop sustainable integrated water resources management through raising awareness, sharing knowledge. The problems need to be solved by building resource capacity in the most critical areas of water resource management simulated by game-based learning tools presented by Chengzi Chew [8]. The concept of the game is to create an ideal world with harmony between the ecosystem, natural resources, civilization and it's needs. The core game mechanics of Aqua Republica represent the virtual environment of water resources; simulation focuses on creating the perspective and real environment which represents the ecosystem. The factors of ecosystem services combine two layers – the core game layer and the hydrology model and water resources. The hydrology model and water resources are researched and presented by MIKE BASIN. The MIKE BASIN model is used to explain the water resource sharing in terms of local river basins. The model is calculated based on energy, freshwater, water regulation, climate regulation, natural hazard regulation and nutrient cycling. The concept links all these factors to this layer. The game layer is represented in a 3D map and calculates a score depending on the input of the player. Every action of the game effecting the water environment is calculated in the MIKE BASIN score considering every factor of the MIKE BASIN model.



a)

b)

Fig. 1. a) The Mike Basin model factors and (b) Representation of the core game mechanics

The player can have various decisions through the game mechanics in order to manage the water resources in an interactive and engaging way. Also, they can study the connectivity of water resources during the game. The player can organize and choose from options in order to increase productivity of energy, food and water resources in many situations like disasters or growing demand of people around the city. The game concept is based on the popular turn-based strategy type games where players need to complete tasks by using the options provided in each turn to balance between resources. Players have fifteen turns to control the simulation world of water resources where they should maximize their scores by choosing the best options provided.

3 Experiment Design

Our research is based on the competition Eco-challenge 2017 in Chiang Mai University (Figure 2) using Aqua Republica. In the Eco-challenge students of ages 14–18 were recruited. The experimental design for this research was focusing on the research hypothesis: "Which game element, Leaderboard, Cooperative or Awarding badges can improve the learning performance of students the most? ". The participants were divided into two groups for the experiment in order to investigate the effect of each game element concept. There were two research questions: "which group ("Gamified" and "Non-Gamified") is better in terms of learning performance?" and "which game element is the best to improve the learning process of participants?". In order to see the result, the participants were randomly assigned to the two different "Non-Gamified" and "Gamified" groups of two class-room settings. The overview of the methodology is shown in Fig. 3.

However, in the Eco-challenge 2017, there were two types of competitions, namely the audition and the final round. In the audition round we could set up the rules independently followed by the partners depending on each nation in order to avoid problems in the future. For this research, we investigated the effect of three game elements, namely leader boards, cooperative- and awarding badges. For that reason, we separated the game into four sessions with one session focusing on training and the next three sessions testing thee game elements. The competition started at 10.00 a.m. and lasted until 3.00 p.m. with a lunch break after finishing session two around 12.00 p.m. We didn't permit students of any groups to see each other or to talk to each other. After the opening ceremony of the eco-challenge 2017, we started with an initial session. This session was necessary since most of the participants no had experience of the core version of Aqua Republica before. Additionally, the purpose of the initial session was to make participants get familiar with how the game mechanics of Aqua Republica work. In the second session a real analysis was carried out which focused on determining the learning outcome of cooperative learning. The details of this analysis will be discussed later.

In our experiment the Gamified and Non-Gamified groups were compared. Thus, for each group, we compared each session with the previous one to see the learning and behavioral outcome of the participant verifying the knowledge sharing concept. In the Gamified group in the third session, we focused on the behavioral change caused by the introduction of the leaderboard. The idea behind the leaderboard was to introduce a score system covering all participants through which participants can follow their ranking positions and position changes. Finally, the last session observed the learning performance effect of real awarding badges applied only in the Gamified group awarding the top five scorers with badges. In our experiment, the top-five players obtained the honor of real badges from the dean of the faculty.

3.1 Participants

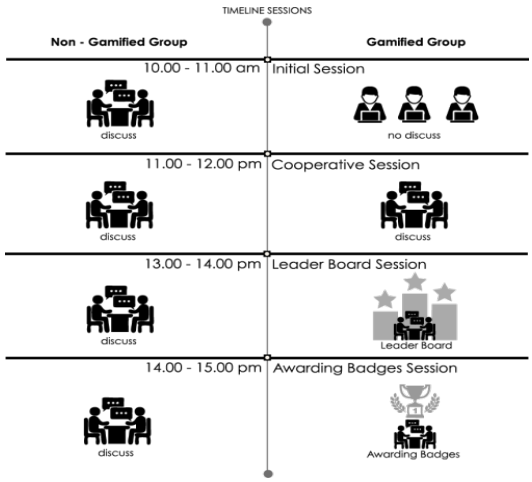
Altogether 96 students from secondary schools around the Chiang Mai province participated in the experiment. We recruited 5-10 students from each school ages 16-18

following the rule of Aqua Republica. There were two groups: "Gamified" and "Non-Gamified" and each group had 48 students. The selected participants all had previous experience with online mobile and desktop applications and with strategic games. However, it is very important to note that some students who participated in this year's competition may had prior experience through last year's competition using the Danida version of Aqua Republica but it didn't affect their performance too much because the Eco challenge 2017 changed the version of the core game of Aqua so that the game score was calculated differently and the game was totally different from last year's game to make sure that none of the participants who joined the Eco-challenge 2017 Republica has any advantages or disadvantages. However, for that reason, we also added a new rule that the top-five scorers of the previous year couldn't join the Eco-challenge 2017.

Fig. 2. Participants of Eco challenge 2017 in Chiangmai University

3.2 Procedure

In this session, we describe each step which was applied in the "Gamified" and "Non-Gamified" groups. Every participant was assigned individually to the three phases of the experiment and to the training phase to make them be familiar with the game. Every phase had a time limit of one hour because the average time for finishing the Aqua Republica game is 15 minutes, and players should not play each match more than 4-8 times in order to maximize the learning outcome of the game-based learning.



a)

b)

Fig. 3. a) The overview of methodology and (b) The information of Gamified system

Initial session: The purpose of this session was to make participants of both "Gamified" and "Non-Gamified" groups be familiar with the core game mechanics of Aqua Republica. Both groups were administered to determine basic control and skills for the user interface of Aqua Republica. For the training, all teams were given a personal computer desktop to prepare for research and competition. It should be noted that the

score in this session was reset after finishing the initial session and students were not allowed to talk with each other.

Cooperative session: Each participant of the initial session was asked to pair up with their team who registered as a team in the competition. Then, the cooperative session started immediately. Each team could use one personal computer desktop. Additionally, we allowed the members for each team to discuss and share the knowledge or tactic on how to get the highest score in the game but it was not allowed to talk with other teams. This session had a time limit of one hour, technically the score for each team was recorded on the server every two minutes with the aim to carefully analyze the results of behavioral outcomes in details for each team.

Leader board session: Eco-challenge has two sessions, a morning and an afternoon session. The afternoon session began at 01.00 pm after a 1-hour lunch break However, it should be noted that during lunch students were not allowed to talk to other teams because of research-related reasons. In the leaderboard session, team members of the "Gamified group" were allowed to observe the real-time leaderboard in two ways. First, the administrator turned on the projector in order to show the leaderboard on the big screen in front of the room of the competition. Second, on a piece of paper attached to the table we provided the URL and the login for access to see the leaderboard via a web browser. On the other hand, for the "Non-Gamified group" no additional conditions were added compared to the previous session. Participants in this group had to increase their scores in a similar way like in the previous session. The time limit of this session was still one hour. The scores were recorded in the server in order to see the effect of leaderboard on the gaming behavior of participants. The purpose of this session was to make participants of both "Gamified" and "Non-Gamified" groups be familiar with the core game mechanics of Aqua Republica.

Awarding badges session: The aim of the last session of the competition was to study the effect of awarding badges on the learning and behavioral outcomes. Behavioral outcome refers to the motivation of students who prefer real awarding badges to virtual badges. It is important to note that the reward of badges was not declared before the start of the competition. The participants of the "Gamified group" were informed that the players of the top five scores could get real trophy badges. On the other hand, the "Non-Gamified group" wasn't provided any information, they just kept playing collecting scores without seeing the leaderboard and knowing about the extra awarding badges. In technical terms, the time limit set up was one hour for the awarding badges session ending at 03.00 pm automatically disconnecting from the server.

Purpose of the measurement: The most important part of the Gamification research was the measurement of behavioral outcome. In general, the research studies investigated how to measure the direct link between the Gamification concepts applied to education in order to monitor the effect of game elements for promoting better performance in education. Unfortunately, there are no scientific researches to prove any reliable standards for the method of measurement. Generally, it is reasonable to assume that the instruments are reliable and could be used to determine the effects of behavior outcome. Self- report measurement was reported to study the effect of Gamification. Hamari et al [11][12] and related studies directly find the relationship between the affordances on the behavioral changes. However, in our experiment, it was very difficult

to measure the outcome by self-report in the investigation of the effects of each game element. For that reason, we aimed to select the actual use of numerical indicators instead of self-reports. To propose the method, we present the Metric system of measurement which was used in the experiment consisting of two aspects of performance as follows:

The purpose of indicator:

- ABT (Average of basin score per time unit)
- APT (Average of playable round per time unit)

First, we propose the performance of learning defined as ABT (Average of basin score per time unit). The concept of this indicator is to determine the efficiency of the performance. This indicator shows how well the player understands the connectivity of water management based on the score per time in Aqua Republica. The Aqua Republica basin score is calculated from the hydrology-based model which is used widely in the simplification of real-world systems incorporating water resource management, food and fund resources. 1. shows the equation

$$ABT_t = \frac{1}{n}\sum_{i=1}^{n} BS_{i,t} \tag{1}$$

Where i is the team participant, BS is Basin score of participants i at the time t.

The value of ABT can measure the learning indicator of participants in understanding the connectivity of water management proven by the Mike basin model [8]. Second, based on the research of observing the behavior outcome related to game elements, we propose the behavior indicator defined as APT (Average of playable round per time unit).The purpose of this indicator was to measure the behavior outcome in terms of motivation for boosting up the action time by monitoring the number of finished game sessions per time unit. Note that in order to calculate the indicator we used five minutes as a time unit for both APT and ABT which we summarized in the equation 2.

$$APT_t = \frac{1}{n}\sum_{i=1}^{n} PR_{i,t} \tag{2}$$

Where i is the team participant, PR is Playable round of participant i at the time t.

In our experiment, the scores are recorded and analyzed based on the game server of Aqua Republica. However, in more details, the indicator of ABT calculated from the basin score shows the performance of the students in five separate factors per game round (Figure 4): food, eco system, funds, food and energy. All game factors were calculated as basin scores after 20 turns and the final basin score was displayed. For the indicator of APT, there was no condition or limit regarding the number of game rounds.

Fig. 4. Five factors to calculate the basin score.

4 Results

According to data collected from the last session, we represented the properties of ABT in Graph 1 and table 1 in terms of raw data and angle difference for all sessions of the Gamified and Non-Gamified groups. This graph was calculated from the ABT score for each group as we mentioned before. For the initial session, without any factors included, the average score of the Non-Gamified group was a bit higher than that of the Gamified group (1300 and 1500 respectively).For the cooperative session, the Gamified group was added the factor of knowledge sharing where the team could share the knowledge and plan the strategy to increase the score which resulted in the Gamified group having a higher average score than the Non Gamified group (2000 and 1500 respectively) and the scores of the Gamified and Non-Gamified groups continued to show an even bigger difference in the Leaderboard session (4000 and 3000 respectively). In the last session, the score of the Gamified group was almost two times higher (7000 and 4500) than that of the Non-Gamified group (7000 and 4500 respectively). A more detailed explanation will be provided at the end of the experiment.

In the data experiment, the average Basin score of the Gamified group has exceeded the score of the Non-Gamified group with more than 56% considering the total score (graph 1). Additionally, we represented the data in terms of a normalized slope which is calculated by connecting the starting point of each session with the endpoint of each session as shown in graph 2 where data was collected from the ABT value. Each line slope of the Gamified and Non-Gamified group is basically an angle difference which can clearly measure the difference between each group. In the same way, the angle difference between the Gamified group and the Non-Gamified group is the greatest in the leaderboard session (degree change = 50). In summary, Fig. 5, 6 and table 1 of the ABT value proved that all game elements in Gamified sessions have a significant impact on gamer performance.

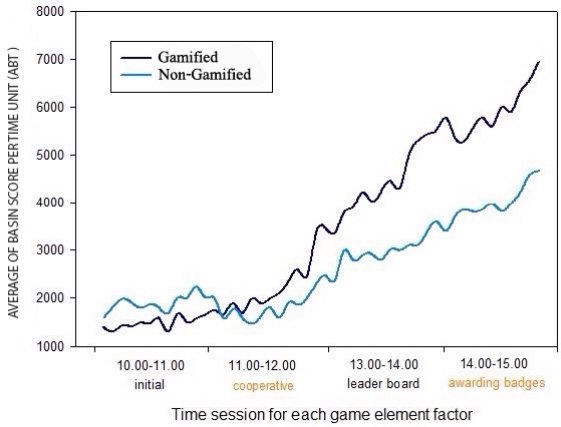


Fig. 5. Graph of the basin scores per time unit (ABT)

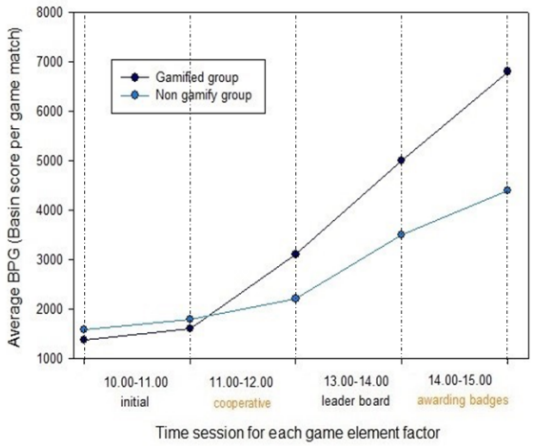


Fig. 6. Graph of the normalized slope of ABT (basin scores per time unit)

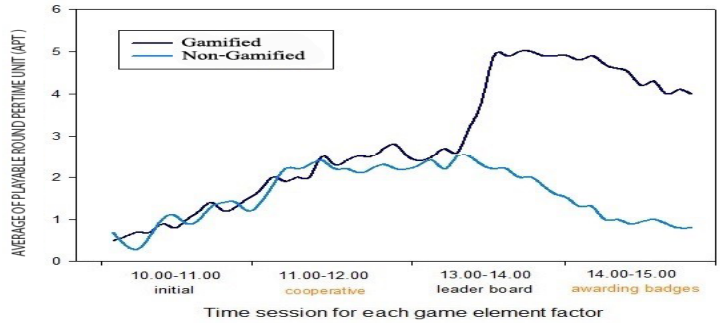
Table 1. Angle difference (degree) of ABT for each game element

Value of ABT (Average basin score per time unit)		
Session/ game element	***Gamified (unit/degree)***	***Non-Gamified (unit/degree)***
Initial (no game element)	+6	+6
Cooperative	**+33**	+11
Leaderboard	**+50**	+30
Awarding badges	**+39**	+21

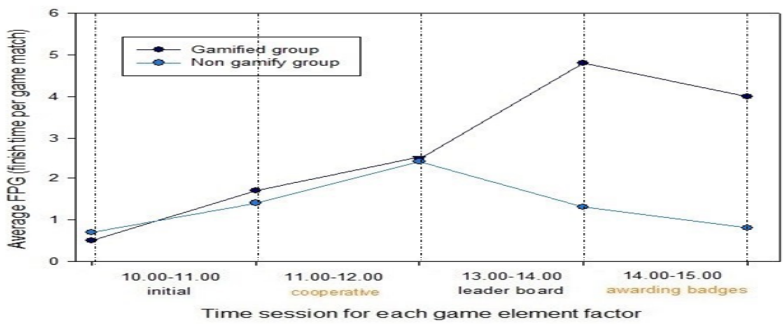
Besides the value of ABT, we also represented the value of APT in the same way. The data analysis of Fig. 7 and table 2 displays the significant difference between the Gamified and Non-Gamified groups. Similar to the previous ABT value, the initial and

cooperative sessions don't show any significant difference in terms of data. However, in the leaderboard session the Gamified Group reached an APT value more than two times higher than that of the Non-Gamified Group (APT = 5.2 and 2.6 respectively). Furthermore, the awarding badges session also show a drop in the scores meaning that badges do not have too much effect on any of the groups. Summarizing the results of the APT data, Graph 3 and table 2 shows that leaderboard as a game element had a significant effect on player performance but not cooperative and awarding badges.

Finally, the data from table 1 and table 2 proved that applied game elements improved the students' learning performance in Game-based learning (answer for research question 1). Based on data of Table 1 and Table 2 the value of angle difference (+50, +49) showed that the leaderboard has the best performance to improve the learning process of students (answer for research question 2). Our findings have implications for the applied game elements to improve the learning performance in the field of education. Since the implementation of each game element takes time and costs a lot, the results show that if one must choose between 1 or 2 options due to some limitations, it is worth considering the implementation of a leaderboard first.



a)



b)

Fig. 7. Graph average: (a) and Normalized slope (b) of playable round per time unit (APT) of Gamified and Non-Gamified groups.

Table 2. Angle changes of APT for each game element

Value of APT (Average of playable round per)		
Session	***Gamified (unit/degree)***	***Non Gamified (unit/degree)***
Initial (no game element)	+31	+20
Cooperative	+22	+27
Leaderboard	**+49**	-29
Awarding badges	-20	-16

5 Conclusion

In this study, we proposed to study the student behavior for learning through Game-based learning of water management including the concept of Gamification and with the aim of boosting learning through game elements. There were three game elements taken into account during the assessment: cooperative badges, leaderboard and awarding badges. In summary, of the overall results showed that game elements have a great effect on the learning performance measured by ABT (Average of basin score per time unit) for the "Gamified group but there is no significant impact on the behavior outcome as regards the overall performance of APT (Average of playable round per time unit). However, the learning outcomes of the "Gamified" group show that this group's performance is more than two times higher than the performance of the "Non-Gamified" group. Additionally, the game element of leaderboard was proved by both the ABT and APT indicators to have a significantly positive effect on boosting student performance compared to the effect of cooperative and awarding badges. Our research recommends to consider implementing the Gamification concept of leaderboards first in order to maximize performance.

For future research, we suggest studying the effect of other game elements such as levels, quests and avatars. Applying the concept of the Gamification framework with game elements in the classroom provides student engagement and enjoyment in many difficult conceptual courses.

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