Gamification Approach towards Engineering Students' Engagement in Online Learning

Lee Chin Kho, Sze Song Ngu, Annie Joseph, Dyg Azra Awang Mat, Liang Yew Ng, and Ji Liang Hau

***Abstract*—Many engineering students might encounter difficulties understanding certain topics of related courses. They feel frustrated when the teaching method is dull, and the teaching materials are not attractive. All these may lead to the demotivation of the students toward the courses. Fortunately, there are tons of teaching techniques that are introduced to help in boosting students' engagement in the classroom, such as inquiry-based learning, project-based learning, service-based learning, and others. These techniques require the student's engagement, which eventually improves students' concentration while motivating them to practice critical thinking skills. It may promote positive learning experiences. However, engineering courses comprised of various complicated theories, calculations, projects, and assignments, which may burden some students. Furthermore, in addition to the COVID 19 pandemic, the students only attend their classes online, making the learning process even more independent and challenging. Therefore, this study aims to explore the gamification approach for engineering students to increase their engagement while learning online. A batch of 116 students from the Bachelor's Degree of Engineering in Electrical and Electronics offered by Universiti Malaysia Sarawak (UNIMAS) are invited to participate in this study. A gamified learning model that consists of four stages is created in the online platform for the second-year KNR2443 Electrical Engineering Technology (EET) course. This gamified learning model integrates students' rank, interactive map, and video guide. A survey related to gamification is collected from the EET students who completed the gamified learning model. The results are generally positive and indicate the gamification approach can potentially improve the engineering students' engagement and enjoyment in the learning process.**

***Index Terms*—Engagement, gamification, online learning, engineering.**

I. Introduction

Engineering course is well known as one of the toughest courses compared to other non-technical courses. The main reason is that engineering courses are derived from natural physic phenomena and calculations. With the vast concept of certain theories, implementing those theories into application needs a great amount of thinking skill and understanding. Moreover, all of these have tons of formulae and complex mathematical calculation tag along. Without any one of them, the implementation of certain applications might not work. Therefore, without full attention, interactions such as discussions, quizzes, questions and answers in class, and back time revision, it is challenging for the engineering students to understand and implement all the theories, concepts, designs, and calculations taught in class.

Most educators get used to providing lectures about related topics in front of students using merely slide show presentation format. However, it is not enough for engineering students to understand the core of the theory. Moreover, this teaching method is outdated as students are surrounded by many more attractive events. For instance, smartphones are able to provide all sorts of entertainment. Therefore, students tend to lose attention during the class and start watching videos, playing games, communicating through social media, and doing other activities intentionally while the class is ongoing. If educators can turn this enjoyment and excitement obtained from the entertainment into teaching and learning, the students will not get bored while increasing the student's engagement in class.

Most engineering students are attached to the computer, as they need it to perform simulations, modelings, and prepare reports or assignments. This environment implies that most engineering students tend to play games as they are exposed to computers more often. So here comes the role of computer games, mainly to promote mental stimulation. The coordination skills for physical movement, visual, and audio are needed when playing computer games, which means more brainpower is needed. Besides, playing computer games also can improve students' concentration. It is known that when playing games, the players can sit for hours without losing much attention and energy because of the fun and excitement within it [1]. Moreover, problem-solving skills can also be improved when playing computer games. This improvement can be achieved because most computer games have a definitive objective, rules, and restrictions that force players to solve the problem or think of alternative routes or moves to complete the games. Therefore, gamified elements have been actively included in the learning activities as a new way to improve students' engagement [2]. According to [3], students would benefit from more engaging learning material because this is how they have acquired their knowledge. Therefore, to increase the engaging learning environment, the gamification approach has been promoted.

Gamification can be defined as utilizing game mechanisms, frameworks, and dynamic forces to promote preferred comportments. In other words, gamification is used as the game mechanism in non-game systems and processes. Gamification has been an elevating technology trend since 2010, reinforced by recent behavioral studies, which exposed that: the desire to improve, achieve, direct our own lives, and connect with others exists within all of us as a core set of intrinsic motivators [4]. That is why the gamified elements

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have caught people's attention and integrated into daily human activities, as they held all the characteristics of the intrinsic motivator. For example, customer rewards programs are used in the supermarket to motivate the customer to purchase. The customers collect points for money spent in the supermarket in exchange for some devices or services as rewards. This is comparable to game players as they collect points in each stage of the computer game to win the badge or other rewards.

Gamification is getting popular in education and used to improve engagement in class. It has been widely introduced in school and proven to improve motivation in learning processes [5]. Previous studies on the gamification approach for engineering students at the university level have been done in [6], [7]. The studies were conducted based on the physical learning process in the classroom. The results showed that the majority of the engineering students like the gamification approach in the teaching and learning process and agreed that it could improve engagement in the classroom.

This paper further studies the gamification approach for engineering students in UNIMAS based on the online teaching and learning process. A gamified learning model with four-game stages is created in an online learning platform and participated by the second-year students for the Electrical Engineering Technology (EET) course. This gamified learning model has integrated students' rank, interactive map, and video guide. Furthermore, a survey related to gamification is collected from the students who have completed the gamified learning model. This survey is mainly to obtain feedback on the gamification experience of the students.

The remainder of this paper is arranged as follows: background and motivations, which summarizes the related papers and provides the motivations behind this study; the methodology, which explains the development of the applications; the results, which describes the finding of the students who complete the gamified learning model; and finally, conclusions are provided while ideas for future works are proposed.

II. Background and Motivation

Several papers were reviewed before the initial development of this study. A brief description of those works is presented in this section. There are numerous types of student-centered teaching methods introduced by educators to replace the traditional direct instruction teaching methods, such as inquiry-based learning, project-based learning, service-based learning, and others. Inquiry-based learning is a common learning method requiring self-exploration, sitting for standardized assessment, and reporting the progression. However, this kind of learning approach is not suitable for numerous students as it needs students to have high awareness to perform it. Besides, project-based learning is a method that requires the students to play an active role in the learning process. However, this kind of learning method is limited and time-consuming, where the project may take tons of time to complete. Meanwhile, the service-based learning method combines learning in the class and engages well in real-life experience in serving the community. However, the service-learning approach is limited to certain fields only and it is not very compatible with engineering courses that require a deep understanding of concepts and calculations.

The most suitable learning method for engineering courses, particularly to increase students' engagement, still needs further investigation. In this study, the gamification approach is selected because most engineering students have experienced playing computer games. Besides, the trait of unknown elements in gamification, which encourages peers to compete for a higher scoreline, eventually making players more focused and willing to learn to solve the games. This method is effective for the courses that need better understanding by attracting the students in the class and increasing the interaction between themselves so that students can be motivated to achieve the course's learning outcome. The authors in [8] presented a survey on students' experience of playing a gamified quiz in the classroom. They recognized the gamification method serve as a better tool in teaching method to a certain degree.

Games can be divided into several types such as adventure, arcade, board, action, and others. However, all the games share a common feature: progress towards the defined objectives. For example, there is a win, lose or draw for every board game. Within the game, it can be a combination of different kinds of mechanisms. For example, the narrative story presented the game, video of guidance, and leveling, which allows users to pass after collecting the predefined amount of points, badges that serve as rewards for completing actions, and public ranking of users according to their achievements [9], [10]. A paper proposed using boardgame features with the assistance of QR scanning to design the gamification activities. In the activities, Card-game, Slides, and Learning Sheets (CSLS Gamification Model) are implemented to understand the organic chemical structure and functional groups, resulting in better collaborative learning and learning motivation [11].

Another paper proposed more interesting gaming elements, which are combat system, leveling an,d badges. The gaming model Coverbot, equipped with the learning environment for statement coverage. In this game, the student as a player character who survives from the enemy's attack depends on the code written and executed line. The player who managed to write a lesser code lines to execute an operation of the required questions, the better is the score. This kind of gaming element can increase the competitive spirit among the players and trigger the potential of certain students with high efficiency in solving problems [12].

In order to have better university students' involvement in the education process, gamification with and without Learning Management System (LMS) Moodle is studied [13]. The LMS Moodle is a learning platform built with different gamification features to enhance students' interest in the courses and inspire them to continue learning. It provides a system to create own avatar by uploading photos and setting up all the desired patterns. Besides, students as avatars are asked to solve a certain task to complete a particular condition before entering the next quest. After completing all the tasks, the score is displayed according to their ranking with certain badges. Based on the result, this tool is great in

increasing students' motivation and at the same time encourages them to study with fun.

Based on the review, there is numerous way of implementation of gamification in the teaching and learning process. However, the type of gaming elements that are more suitable for the engineering courses that consist of complex theories and calculations in online classes need to be studied. Therefore, this study answers the question, "How to increase the engineering students' engagement by using gamification approach for the online class?". Moreover, an improved gamified learning model is developed compared to the previous study [14].

III. Methodology

Engineers play the role of developing new technological solutions. Therefore, they must be critical yet creative, curious yet capable, and well prepared with related knowledge. Engineering courses are one of the hardest fields due to the complicated theoretical concepts, a deep level of complex calculation, and the difficulty of combining mathematic and theory to create products. As good engineers, they need to fully understand the related concept theory. In order to achieve this, a lecturer needs to be fully equipped with understandable materials of the courses and some mysterious attractions that caught the students' attention. Therefore, the gamification approach can be one of the suitable selections used in teaching engineering courses. Compared to other teaching approaches such as inquiry-based, project-based, and service-based learning, the gamification approach is packaged with interesting elements that attract the most for engineering students.

As mentioned above, this paper extends the previous study on "A study on Gamification towards Engineering Students' Engagement in the University Level" [14]. However, the teaching and learning process studied in this paper are completed online, while the physical class is conducted in previous study. The lectures are conducted synchronously using online video conference tools such as zoom, Webex and google meets. The improved gamified learning model is developed to get the students' attention. Besides, it generates a better environment of thirst in seeking information. The element that can boost students peer competition and the feeling of fighting spirit in achieving the target is also added into this gamified learning model. In addition, improvement of the teaching materials is fused into the gamified learning model to achieve the balance of enjoying the game and gaining knowledge

Firstly, the gamified learning model is built with the following elements: narrative story, students' rank, interactive map, and video guide as the reference or hints to the students. An additional element added is the staging requirement to enter each stage of the game as shown in Fig. 1. Next, the students' rank system based on the accumulative score is used. The participants will be ranked according to their accumulated score, as shown in Fig. 2. By doing this, certain students will easily get a trigger and try their best to get a better score in the game. The fighting spirit among the peer can also be created and increase the engagement in the class. Upon getting introduced to the gamified world, the students are then asked to participate in the online gamified learning model embedded in the online learning platform of UNIMAS, which is also known as UNIMAS ELEAP.

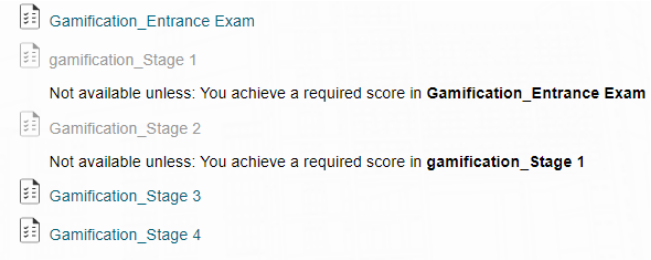


Fig. 1. Entrance requirement.

Fig. 2. Rank awarded according to the accumulative score.

A. Target Group

The student from the second year first semester for cohort 2019/2020 course of Electrical Engineering Technology (EET) is invited to participate in this study. All of these students are from the programme of electrical and electronic engineering. The total number of students in the EET course is 116. Although all students responded to the invitation, only 108 students successfully entered stage 1 of the gamified learning model. First, students need to log in using their username and password to the EET course in the UNIMAS ELEAP. Then, the student acts as a player while joining the gamified learning model attached to the course learning outcome (CLO) 2. The CLO 2 for the EET course is to analyze the multiphase system in electrical engineering technology. This CLO is selected because it consists of the fundamental electrical theories and calculations that electrical and electronic engineering students must understand. The ELEAP platform is also served as the tool in collecting the students' profile and data. The number of respondents for each stage of the game is shown in Table I.

TABLE I: Number of Participants

Stage of game	Number of participants
Entrance Level	116
Stage 1	108
Stage 2	106
Stage 3	107
Stage 4	108

B. Game

In this study, the narrative story, students' rank, interactive map, video guidance and entrance requirement are implemented. The entrance requirement is the new gaming elements added to boost the peer competition and strengthen the knowledge on electrical engineering. The students need to obtain a targeted score at the entry-level before advancing into stage 1 of the gamified learning model. The entry-level is shown in Fig 1. The gamified learning model consists of four stages, and each stage is attached with necessary video learning materials, called rest points in the interactive map that participants are advised to watch. The video content is improved by having some applications of the concept theories compared to previous studies. The upgrading of

content in the video learning materials serve a better teaching material and more understandable teaching. Fig. 3 shows one of the video learning materials at the rest point in the interactive map. To avoid losing the score, participants should watch carefully and fully understand the video content before starting the game.

First, the participants need to enter the gaming learning model and the narrative story about the game, as shown in Fig. 4. Next, the participants need to read and understand the story to know their role in the game. Then the participants are redirected to the map, as shown in Fig. 5, where participants for each stage conquer them. In this interactive map, participants are not allowed to advance to the next stage before finishing the current stage. This requirement is to ensure that the participants understand well each stage of the gamified learning materials.

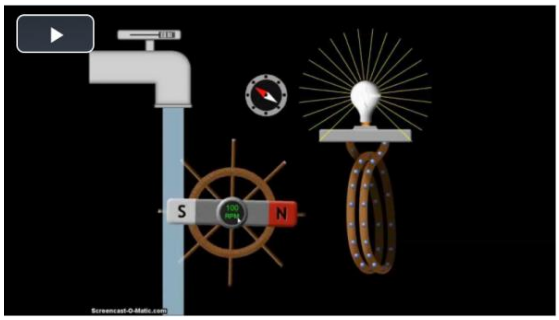


Fig. 3. Example of video learning material.

Fig. 4. Narrative story.

Fig. 5. Interactive map.

C. Stage of Game

As mentioned, the gamified learning model consists of one entry-level and four stages, and participants need to fulfil the requirement of stage game from one to another before continuing. For example, the participants need to correctly answer four out of seven questions in the entry-level to enter stage 1. The question format for entry-level and stage 1 are multiple-choice questions related to alternative current, direct current, and root means square. In order to enter stage 2, the accumulative score from entry-level and stage 1 must be above 50% out of the total marks.

In stage 2, the participants must show how to calculate and analyze the results based on the given circuit. However, in stages 3 and 4, no entrance requirement is needed. The participants who fail to enter stages 1 and 2 can still join the stage 3 and 4. The questions in stages 3 and 4 are more challenging. The questions are more related to case study and design. Below are the details of the content for each stage of the game:

- Stage 1- Tutorial video-based game and answering the question related to A.C., DC, and RMS.
- Stage 2-Tutorial video-based game and answering questions related to RLC circuit analysis.
- Stage 3-Tutorial video-based game and answering questions related to impedance and reactance
- Stage 4-Tutorial video-based game and answering the question related to delta, star circuit connection.

D. Data Collection and Analysis

After the students complete each game stage, their progress and score are fully recorded in the online learning platform UNIMAS ELEAP. The data collected are starting time, ending time, score, duration, and personal information, as shown in Fig. 6. The collected data can be downloaded and observed to investigate students' engagement in the gamified learning model. Besides, the collected data can also be used to ensure this gamified learning model successfully improves the understanding of the engineering topics. In addition, the participants are required to fill out a survey form, as shown in Fig. 7, after completing the game. This survey mainly obtains the participants' perspective on implementing game mechanisms on online teaching and learning in the engineering course.

State	Started on	Completed	Time taken	Grade/10.0000	Q. 1 /10.0000
Finished	11 December 2020 3:25 PM	11 December 2020 3:25 PM	26 secs	3.3333	3.3333
Finished	11 December 2020 3:25 PM	11 December 2020 3:33 PM	7 mins 34 secs	10.0000	10.0000
Finished	11 December 2020 3:26 PM	11 December 2020 3:35 PM	9 mins 5 secs	10.0000	10.0000
Finished	11 December 2020 3:29 PM	11 December 2020 3:31 PM	1 min 56 secs	10.0000	10.0000
Finished	11 December 2020 3:31 PM	11 December 2020 3:32 PM	1 min 28 secs	10.0000	10.0000

Fig. 6. UNIMAS ELEAP online learning platform.

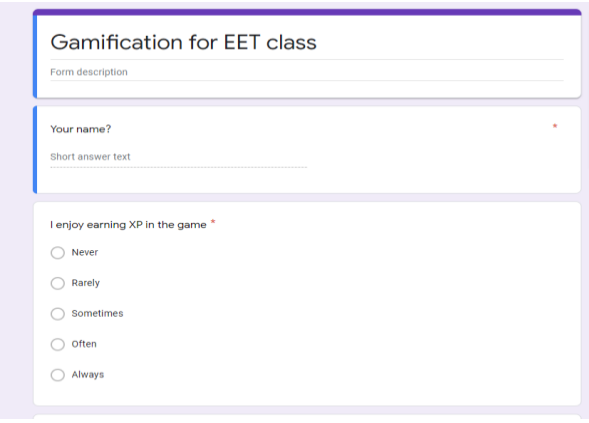


Fig. 7. Example of the survey form.

IV. Results and Discussion

A. Game Model Analysis

116 students from the second year 2020/2021 course of Electrical Engineering Technology (EET) are invited to participate this gamified learning. The participants are encouraged to complete four stages of games, which cover different learning topics of this engineering course, such as alternating current (AC), direct current (DC), root mean square (RMS), resistance, inductance and capacitance (RLC) analysis, impedance, reactance, delta connection and star connection analysis. To solve each stage, participants must understand the theoretical and calculation concepts.

The effectiveness of the gamified learning model in the perspective of engagement and motivation is evaluated. The score in stages 1, 2, 3 and 4, the starting time, and the duration taken to complete the game is analyzed. The results are presented in Fig. 8(a)–(d). From Fig. 8(a), 60% of the participants, take four to five minutes to complete stage 1. This is followed by 20% of participants who complete the stage 1 in three to four minutes. There is only one participant who completes the stage within one minute. Overall, 93% of participants spend over three minutes for stage 1, which mean the participants are taking the game seriously. Furthermore, the participants spend most of the time solving the task in the game, which implies that they are fully engaged in this learning method.

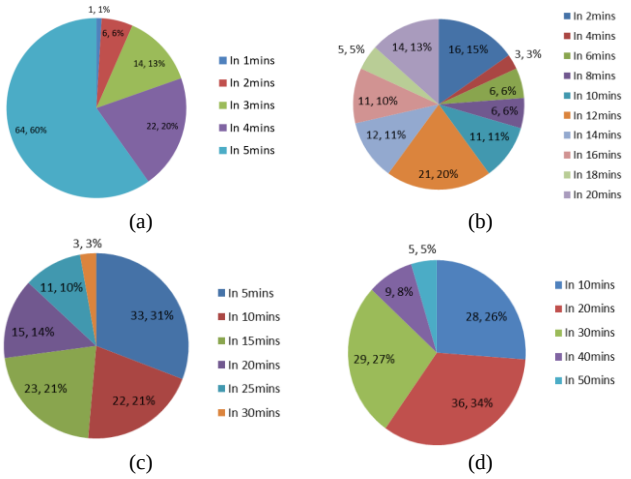


Fig. 8. Number of the participants versus the duration to complete (a) Stage 1, (b) Stage 2, (c) Stage 3, and (d) Stage 4.

Fig. 8(b) shows the duration taken by participants to complete stage 2. The participants are given 20 minutes to complete this stage. Each duration range in this stage has a small number of participants. The highest percentage of participants, 21% spend 10-12 minutes to complete stage 2, which is more than half of the total time given for the game. Then, 16 participants spend two minutes and 14 participants spend 18-20 minutes. The percentage of participants who spends more than 10 minutes and less than 10 minutes is 51% and 49%, respectively.

In addition, Fig. 8(c) shows the duration taken by participants to complete stage 3. Most participants, 31% complete stage 3 within five minutes, followed by 5-10 minutes and 10-15 minutes, with 21% of participants for both.

Only 3% of participants spend 25-30 minutes to complete the game. Overall, there are 73% of participants who complete the game within 15 minutes.

Lastly, from Fig. 8(d), the highest number of participants, 36 out of 107, spend 10-20 minutes to complete stage 4, followed by 27% of total participants spending 20-30 minutes. Only 5% of participants complete the game within 40-50 minutes. Overall, 87% of participants spend less than 30 minutes for stage 4 which is considered fast. Comparing Fig. 8(c) and Fig. 8(d), the duration taken by the participants to complete the game shows similar pattern. It can be concluded that most of the students tend to finish the game within 10 minutes. Therefore, it is better to design the gamified learning materials for 10-15 minutes per game to ensure the students' attention and performance.

B. Score Analysis

The score of participants at each stage of the games is analyzed here. The highest mark for each stage is 10. Fig. 9(a) –(d) show the scoring for the participants in each game stage. In Fig. 9(a), most participants, 32% score full marks and 15% of the participants score 9 marks. There are 11% participants who score less than 4 marks. However, 73% participants manage to achieve the target score, which is more or equal to 50% to proceed to stage 2. This situation might be due to the limited time given, which is five minutes. As shown in Fig. 8(a) 60% participants, have spent all the time given to solve the problems.

In Fig. 9(b), 64% participants score full marks and only 7% score less than or equal to 4 marks. Thus, the participants achieve a better score compared to stage 1. Furthermore, around 93% the participants score more than 50%, which boosts 28% compared to stage 1.

From Fig. 9(c) and (d), 91% and 82% participants score full marks in stages 3 and 4 respectively. Only 5 participants score less than or equal to 4 marks in stage 3 and 6 participants in stage 4. The participants perform well in these two stages. These might be due to longer time allocated, 30 minutes for stage 3 and 50 minutes in stage 4, causing the participants to have time to check their answers and feel more comfort when solving the problems in stages 3 and 4. From the results in each game, it can be concluded that this gamified learning model had helped increase the students' understanding of the teaching-learning materials.

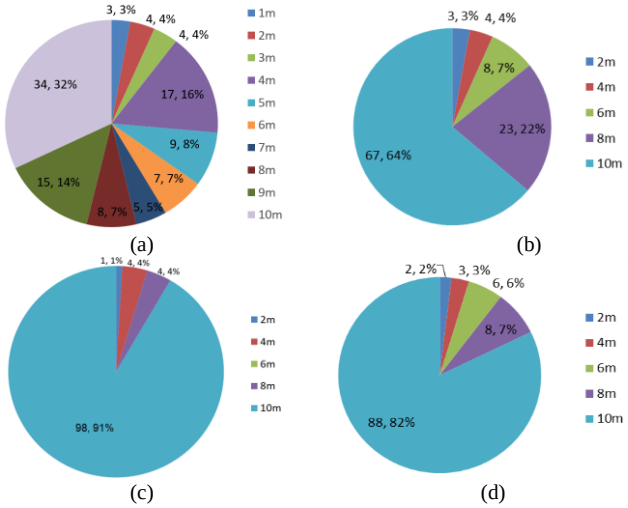
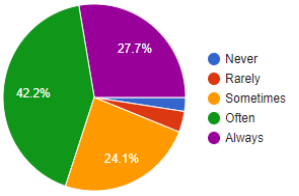


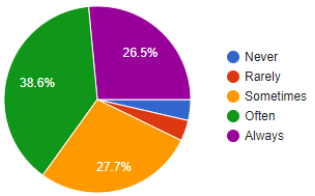
Fig. 9. Number of students for each score in (a) Stage 1, (b) Stage 2, (c) Stage 3, and (d) Stage 4.

C. Feedback Survey Analysis

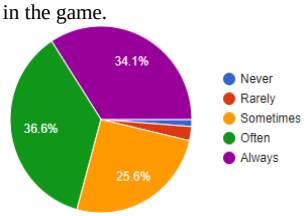
83 out of 116 participants participated in the feedback survey with nine questions. Fig. 10(a) – (h) show the questions and results of the survey.



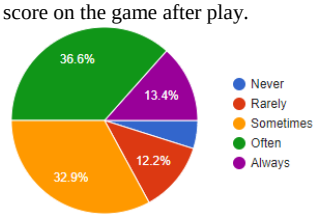
(a). Question 1: I enjoy earning XP in the game.



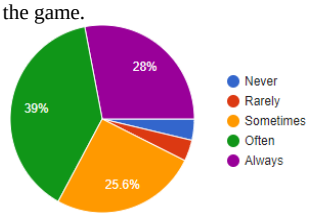
(b). Question 2: I think about my score on the game after play.



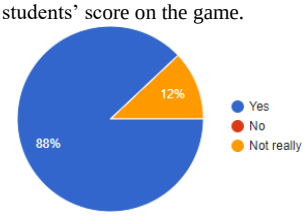
(c). Question 3: I like being good at the game.



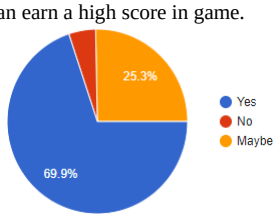
(d). Question 4: I work hard to beat students' score on the game.



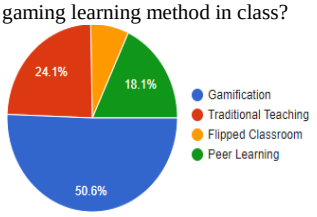
(e). Question 5: It is important that I can earn a high score in game.



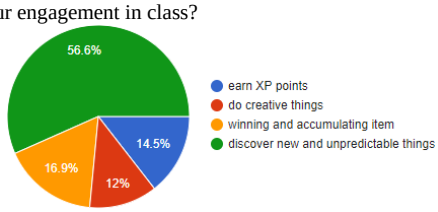
(f). Question 6: Do you like the gaming learning method in class?



(g). Question 7: Do you think this gaming learning method can increase your engagement in class?



(h). Question 8: What type of teaching method you like most?



(i). Question 9: In game, are you motivated by.

Fig. 10. Responses from participants.

The survey results from Fig. 10(f) – (h) are positive to the gamified learning model. For example, 88% of participants like the implementation of gamification in engineering courses, and 69.9% agree that it can increase their online classes engagement. Besides, 50.6% participants prefer the gamification approach compared to other teaching approaches such as the traditional method (24.1%), peer learning (18.1%), and flipped classroom (7.2%).

Questions one to five in the feedback survey are designed mainly to understand participants' behavior toward the gamification approach. For example, 69.9% of the participants enjoy collecting XP points, and 65.1% always think about their score after the game. In addition, 70.7% of participants would like to perform well in the game, but only 67% want to earn a high score. Besides, there are 50% of participants who work hard to beat others' scores in the game. In short, the gamification approach has increased peer competition among the participants and their interest in the course.

Lastly, the gamified activities such as discovery of new and unpredictable items are preferred by most participants, which is 56.6% compared to winning and accumulating with 16.9%, earn XP points with 14.5% and do creative things with 12%, as shown in Fig. 10(i).

V. Conclusion

This paper analyses the data collected from the gamified learning model and feedback survey for the cohort 2019/2020 of the EET course. This study includes elements such as entrance requirements for stages 1 and 2, video learning materials, interactive map, and native story in the gamified learning model. Generally, most participants show a high interest in this teaching method and agree it can improve engagement in the online class. Furthermore, using the entrance requirement in the gamified learning model has shown a better result of participants' performance. This element can ensure that the students who attended the classes understood the content of teaching materials and achieve a deep understanding when playing the game. It also provided a better learning environment with a boost to the fighting spirit, focusing, dedicated mind in learning the courses. In conclusion, the results are generally positive and indicate the gamification approach can potentially improve the engineering students' engagement and enjoyment toward the learning process.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Lee Chin Kho and Sze Song Ngu wrote and attained the grant to conduct this research. Lee Chin Kho wrote the paper as the main author. Annie Joseph and Ji Liang Hau assisted in conducting the survey and analyzing the results. Dayang Azra and Laing Yew Ng improved the paper writing. All the authors had acknowledged and approved the final version of this paper.

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