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# The Impact of Gamification on the Motivation and Performance of Engineering Students Through the Lens of Self-Determination Theory*

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Over the last few years, the concept of gamification has received increasing attention from a number of researchers, especially in education fields, as a tool to improve student performance by increasing motivation and engagement. However, previous research has not attempted to empirically investigate the effects of game elements on the quality of motivation (i.e., intrinsic and extrinsic motivation). Thus, this study investigates in detail the relationship between gamification and motivation through the lens of self-determination theory and seeks to determine whether gamification can maintain student motivation for the duration of an entire semester. The experiment was conducted in the fall semesters of 2016 and 2017 with 122 students (63 in 2016, 59 in 2017). Overall, the results showed that (1) gamification can maintain student motivation over the course of the semester and (2) gamification positively affects intrinsic and extrinsic motivation, negatively affects amotivation, and may, therefore, positively affect academic performance.

**Keywords:** engineering education; gamification; motivation; self-determination theory

## 1. Introduction

Although researchers define the term "gamification" differently according to their purposes and perspectives, most definitions include the following three characteristics in specific relation to each other: (1) the use of game elements to (2) motivate and engage users in (3) non-game contexts. Over the last few years, the concept of gamification has received increasing attention from a number of researchers, especially in education fields, as a tool to improve student performance by increasing motivation and engagement. Although the term "gamification" first appeared in the media in the early 2010's as a novel way to engage students in learning, the concept of gamification, which incorporates game design and mechanics into the learning experience, has a long history. Representative examples include serious games, games for education, and game-based learning. All of these approaches have the same objective: to generate the same motivation and engagement that gamers have toward games in learners toward education [1]. However, gamification is different from these approaches in that it does not require the use of a full-fledged game. This advantage allows many educators or researchers to use a gamification system as a supporting tool in their educational setting, which has resulted in a tremendous increase in literature on gamification. According to Majuri et al. [2], among the 91 empirical gamification studies that utilize quantitative methods, a significant portion (65 studies) report results that positively support the efficacy of gamification. For example, Ruipérez-Valiente et al. [3] applied a gamification system to engineering courses in order to enhance the learning experience of students. Barata, Gama, Jorge, and Goncalves [4] reported the positive effects of gamification on engineering students, showing significant increases in student engagement and participation. De Freitas & de Freitas [5] conceptualized, developed, and applied a gamification system in a computer science class for undergraduate students in order to compare student motivation between gamification and non-gamification systems. Their results showed that students were more engaged in the learning experience and found it more enjoyable when using the gamification system. In addition, Kuo and Chuang [6] reported the positive effects of gamification by

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empirically demonstrating how the theory and practice of online gamification may be used in academia. Recently, Kim et.al. [7] also showed the advantage of a gamification system in an engineering course in terms of student motivation, engagement, and learning outcome.

In previous studies, the most common game elements are those that categorize achievement and progression, including points or score, challenges or quests, badges, leaderboards, ranking, and levels [2]. Since the key features of most gamification systems are points, badges, and leaderboards, as shown in the Table 1, some researchers have suggested that the effect of gamification could be superficial, yielding only temporary benefits and failing to change student learning outcomes over the long term [8, 9]. Hanus & Fox [10] also pointed out that over time, students experiencing gamified learning showed a decline in their motivation that then affected their final exam scores.

Motivation, which is directly related to curiosity, persistence, learning, and performance, is one of the most important psychological concepts in education [14]. Deci et al. [15] define academic motivation as students' interest in learning, valuing of education, and confidence in their own capacities and attributes. Several researchers have applied motivation theory in their attempts to discover what motivates individuals to succeed academically. Deci & Ryan [16] have contributed much to the theory of motivation by developing Cognitive Evaluation Theory (CET) based on findings from numerous empirical studies. This theory explains how external factors (e.g., rewards, feedback, deadlines) support or thwart intrinsic motivation by increasing or diminishing one's feeling of autonomy or competence. Deci & Ryan [16] explained that all external factors have two functional aspects: a controlling aspect and an informational aspect. That is, informational external events increase intrinsic motivation, whereas controlling external events decrease it. For example, if students experience a reward as an informational event allowing choice and providing competence-relevant feedback, it enhances a student's sense of autonomy and competence, which, in turn, supports intrinsic motivation. However, if the reward is used as a controlling aspect of an external event in order to pressure students toward a specific outcome or way of behaving, it diminishes intrinsic motivation.

Over 100 laboratory experiments and field studies have been conducted to support or refute CET based on various types of rewards and other external events and their corresponding effects on intrinsic motivation. The first laboratory study to test the effects of reward on intrinsic motivation was conducted by Deci [17]. He recruited 24 college students and asked them to complete a puzzle-solving task called the SOMA puzzle. The participants in the treatment group were paid \$1.00 for each puzzle they solved, while the participants in the control group received no reward for participating. The experimenter provided free time to participants in the middle of the puzzle-solving session during which they could complete the puzzle-solving task as they pleased while the experimenter observed them and recorded the time that each participant spent engaged in the task. The experimenter used these observations to measure participants' intrinsic motivation. The results of this study showed that the participants who were paid money to play spent significantly less time playing on their own than participants who were not rewarded for playing. However, Deci [17] also conducted another experiment in which he varied the type of reward from monetary to verbal while all other variables remained constant. He found that those who received verbal rewards played longer than those who received monetary rewards alone or both monetary and verbal rewards together, resulting in an increase of intrinsic motivation. Lepper, Greene, & Nisbet [18] also found that rewards had detrimental effects on intrinsic motivation. In this study, participants aged between 40 and 64 months were observed in a free play period to determine their initial intrinsic interest in a drawing activity. A

**Table 1.** Summary of game elements used in previous studies

| Previous Studies | Points or Score | Levels | Badges | Challenges | Reward | Leaderboard | Avatar |
|---|---|---|---|---|---|---|---|
| [11] | | | O | | | | |
| [12] | O | O | | | | | |
| [4] | O | O | O | O | | O | |
| [5] | O | O | | | O | | |
| [10] | | | O | | O | O | |
| [13] | O | | O | | | O | |
| [6] | O | O | O | | O | O | |
| [7] | O | O | O | | O | O | O |

"Good Player Award" card was used as a reward for extrinsic factors. While the experimenters did not provide the reward information to participants in the unexpected-award and the no award groups, they assigned the Good Player Award to participants in the expected-award group. The results of the study showed that children in the expected-award group spent less time on the drawing activity than others in either the unexpected-award or no reward groups. These results indicated that subjects who received expected rewards experienced decreases in intrinsic motivation due to the reward serving as a controlling agent. Since the early studies conducted by Deci [17] and Lepper et al. [18], a number of studies have investigated the effects of external rewards on intrinsic motivation in an educational setting. These studies found that extrinsic rewards such as surveillance [19], deadlines [20], imposed rules and limits [21], imposed goals [22], competition [23], and evaluation [24] decrease intrinsic motivation. A later meta-analysis of 128 laboratory experiments confirmed that, whereas positive feedback enhances intrinsic motivation, tangible rewards significantly undermine it [25]. However, since CET assumes that all motivation stems from intrinsic motivation, this theory cannot explain the circumstance in which activities are not intrinsically interesting but are completed as required duties. As a result, Ryan & Deci [26] further developed the concept of extrinsic motivation in what became known as self-determination theory (SDT). SDT, together with research on individual differences in motivational orientations, contextual influences, and interpersonal perceptions [26], explains how extrinsically motivated behavior can become autonomous. Autonomous motivation encompasses both intrinsic motivation and well-internalized extrinsic motivation such as integrated and identified regulation. SDT proposes that three forms of motivation exist, namely, intrinsic motivation, extrinsic motivation, and amotivation, that, based on the level of autonomy associated with each, lie on a continuum ranging from high to low self-determination, respectively (Fig. 1).

Intrinsic motivation, the first form of motivation under SDT, can be defined as the doing of an activity for its own sake: the activity itself is interesting, engaging, or in some way satisfying. When intrinsically motivated, a person performs an action on a voluntary basis and in the absence of external contingencies [16]. Intrinsic motivation is thought to constitute the most autonomous form of motivation, which satisfies the need to feel competent, autonomous, and related [16]. Thus, activities that lead the individual to experience these feelings are intrinsically rewarding and are likely to be performed again. The second form of motivation is extrinsic motivation, which refers to the doing of an activity, not for its inherent satisfaction, but to attain some separable outcome, such as receiving a reward or recognition from other people. Since external reasons that motivate individuals to perform can differ, SDT specifies different subtypes of extrinsic motivation depending on how internalized the motivation is. These multidimensional extrinsic motivations are divided into external, introjected, identified, and integrated regulations, and they can vary from an entirely external locus of causality to an internal locus of causality, as well as from lower to higher self-determination. External regulation can be defined as the doing of an activity to satisfy an external demand or to obtain an external reward; this regulation represents the least autonomous forms of extrinsic motivation. Introjection and identification are both combinations of internal and external loci of causality. While introjected regulation behaviors are more controlled by external loci of causality, identification regulation behaviors are more controlled by internal loci of causality. The last type of extrinsic motivation is integrated regulation, which is the most autonomous form of extrinsic motivation. Integrated reg-

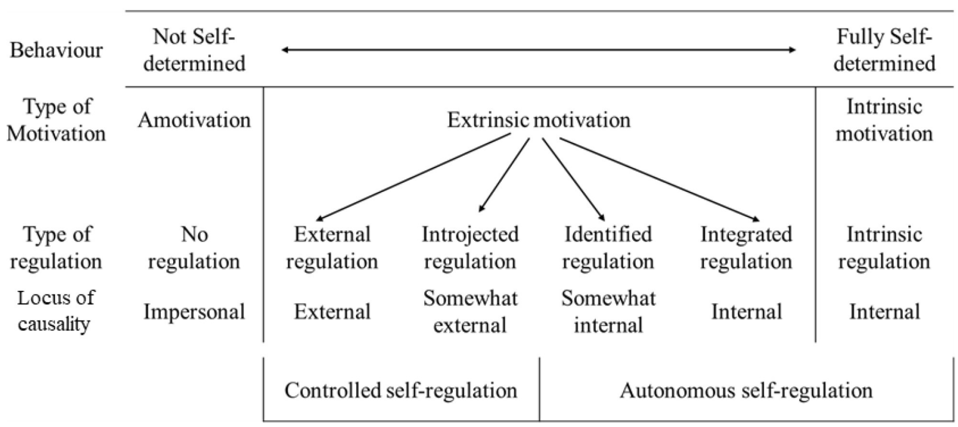


**Fig. 1.** The spectrum of motivation according to SDT (Adapted from [26]).

ulation behaviors occur when identified regulations have been assimilated to the self [15]. Finally, amotivation is the last form of motivation and is considered to have the lowest level of autonomy on the continuum of motivational styles. Markland & Tobin [27] define amotivation as "a state lacking of any intention to engage in behavior." Several studies have tested key SDT constructs in both lab-based and classroom settings, making SDT one of the most empirically validated theories for understanding educational motivation.

As we discussed above with respect to intrinsic and extrinsic motivation, the most central distinction in SDT is between autonomous motivation and controlled motivation [28]. Behavior-regulated autonomous motivations are based on the experiences of volition, psychological freedom, and reflective self-endorsement. Controlled motivation consists of two types of external motivations, external and introjected regulation. Behavior-regulated controlled motivation is a function of external contingencies of reward or punishment that pressure a person to think, feel, or behave in particular ways. In education fields, numerous researchers have conducted experiments in which they used academic motivation to predict students' learning and performance [29–35]. For example, Fortier et al [29] recruited 263 9th grade students and asked them to complete a questionnaire for academic motivation to test the relationship between autonomous academic motivation and school performance. They found that the students who had higher autonomous academic motivation showed higher performance in school. This result revealed that autonomous forms of motivation increase academic performance. Recently, Herath [35] also investigated how college students' motivation may explain learning outcomes in information systems courses. He recruited 160 undergraduate students and 109 graduate students and asked them to complete an academic motivation scale questionnaire. He found that intrinsic motivators are positively related to student perceptions of affective and cognitive learning. However, he failed to find a strong effect of intrinsic motivation on learning in overall grades or exam grades. In addition, he observed that extrinsic motivation has a greater effect on participation grades, suggesting that students who identify external reasons for learning the material tend to put forth more effort in assignments and in-class activities.

Most studies of gamification examine only reward-based gamification systems. For example, students often receive points when they complete a predefined task in the gamification system. These points can then be converted into levels or rankings and can also be used in a leaderboard to encourage competition between students. For this reason, gamification has already become a controversial pedagogical tool, critiqued within a CET framework for diminishing students' intrinsic motivation. On the other hand, gamification provides students with a non-controlling setting in which the implementation of game elements may indeed improve intrinsic motivation by satisfying users' innate psychological needs for autonomous motivation [36–39]. In addition, Deterding [40, 41] has suggested the need for better understanding of the psychological mechanisms underlying gamification. However, currently very few studies have attempted to empirically investigate the effects of game elements on motivation and performance [41–43]. Furthermore, these studies have not considered the quality of motivation (i.e., intrinsic and extrinsic motivation).

While few studies have applied an SDT framework to gamification, several have applied SDT in investigating motivation in computer games and game-based learning. For example, Ryan, Rigby, & Przybylski [44] found that the basic psychological needs of intrinsic motivation predicted both enjoyment and future game play. Sheldon & Filak [45] supported this conclusion, finding that the three basic psychological needs of autonomy, competence, and relatedness within a game-learning context predicted students' affect and performance. Thus, it is important to satisfy students' basic psychological needs of autonomy, competence, and relatedness in a gamification context. Competence, which is the need to be effective and master a problem in a given environment, can be achieved through certain game elements. Difficult goals encourage higher expectations, which in turn increase performance, and the completion of a task leads to a sense of competence and higher satisfaction, ultimately leading to an increase in intrinsic motivation. For example, points can be used to quantify different goals. A level or progress bar visually indicates the player's progress over time, thereby providing sustained feedback. Badges serve as visual symbols of achievement, supporting the competence component of self-determination theory. Leaderboards permit social comparison and a means to display competence to one's peers. Thus, the feedback function of these game design elements evokes feelings of competence, as this directly communicates the success of a player's actions. Autonomy, which is the need to control one's own life, can be understood in a learning context as the ability of learners to make choices about how they learn, given opportunities to take responsibility for their own learning. Since an individual's control over his or her experience is thought to be a crucial component of active learning and is key to the concepts of self-determination theory, it is very important that gamification should provide learners with as much control as possible. If gamification provides multiple paths to achieve the goal, it is possible for players to prioritize and choose which paths are most relevant to them. For example, avatars offer players freedom of choice, while leaderboards and feedback encourage engagement and fulfill the need for relatedness (the need to interact and be connected with others) by providing a choice for learners to either collaborate with or compete among their peers.

In addition, previous research in psychology provides ample evidence that certain forms of rewards, feedback, and other external events can have detrimental effects on intrinsic motivation and hence deter students from a desired behavior. Such results suggest the need for more research on the effectiveness of gamification aspects when it comes to the augmentation of long-term student motivation. Because intrinsic motivation is essential to continuously successful learning behavior, it is necessary to investigate the effect of gamification on students' intrinsic motivation. However, currently very few studies have attempted to empirically investigate the impact of gamification on each type of motivation (internal, external, and amotivation) within a self-determination theory (SDT) framework. Thus, this study investigated in detail the relationship between gamification and motivation through the lens of SDT. In addition, because maintaining student motivation from the beginning to the end of the learning process is a major concern in higher education, we determined whether gamification can maintain student motivation from the beginning to the end of the semester. In this study, we hypothesized the following:

H1: Gamification can maintain student motivation over the course of the semester.
H2: Gamification has a significantly positive relationship with autonomous motivation.
H3: Gamification has a significantly positive relationship with controlled motivation.
H4: Gamification has a significantly negative relationship with amotivation.
H5: Gamification has a significantly positive relationship with learning outcome.
H6: Autonomous motivation has a significantly positive relationship with learning outcome.
H7: Controlled motivation has a significantly negative relationship with learning outcome.
H8: Amotivation has a significantly negative relationship with learning outcome.

## 2. Method

### *2.1 Participants and Procedure*

The experiment was conducted in the fall semesters of 2016 and 2017 with 122 students (63 in 2016, 59 in 2017) with an average age of 20.33 (SD: 0.76). Data were collected from students enrolled in a required introductory human factors course, a third-year undergraduate IE course. The course was offered in a traditional face-to-face classroom environment. Students who participated in this study received extra credit of up to 2.5% of their final grade for each phase in which they participated based on their performance in gamification activity, as summarized in Table 2. For example, if the students signed up for the gamification system, they received extra credit amounting to 0.5% of their overall course grade and could receive an additional 1% extra credit if they met the minimum requirement of creating 3 questions and answering 15 questions. In addition, if students were ranked in the top 5% at the end of semester, they received a further 1% extra credit. For students who did not participate in this study, we provided another extra credit option in order to avoid equity issues.

Participants were first introduced to this study and the gamification website by watching an instruction video in the second week (first lab) of the semester. They were asked to complete a general knowledge test, and they had practice time for gamification activities such as authoring questions and answering questions created by their classmates. The first phase took place from the 5th week of the semester to midterm (through week 8). During the first phase, students could conduct the gamification activities as frequently as they wanted but were limited to creating no more than 5 questions per day and answering no more than 15 questions per day. The week before midterm (week 7), students were asked to complete a questionnaire on their motivation. From the 13th week through final exams (week 16), the second phase of this study was conducted using the same procedure as the first phase. The second questionnaire was collected on the week before final exams (week 15).

### *2.2 Gamification System*

Students conducted two activities: (1) they created multiple-choice questions (MCQs) and (2) they answered their peers' questions in the gamification system. In creating questions, students needed to provide the explanation for the correct answer and

**Table 2.** Summary of extra credit for participating in this study

| | **Extra Credit** |
|---|---|
| Sign up Extra Credit | 0.5% |
| Minimum Requirement Extra Credit (3Q + 15 A) | 1.0% |
| Additional Extra Credit only if students were ranked in the top 5% | 1.0% |

relate the relevant concepts in their own words. In creating and answering their peers' questions, students performed teaching-related activities, which has been shown to be a successful teaching strategy that better engages students in the active learning process [46–48]. Furthermore, these two activities required students to employ the most advanced step in the learning process, creating, which involves designing, constructing, planning, producing, inventing, devising, and making based on Bloom's revised taxonomy [49]. Their questions were evaluated by the students who answered them. The criteria of evaluation were difficulty, quality of the question, and opinion about the correctness of the answer. The question evaluation also provided a section for comments. The gamification system included the game elements of Badge, Score, Avatar, Leaderboard, Level, and Feedback (Notification). Because students knew the point value for completing each task, they were able to calculate their expected score based on the number of questions authored as well as the number of answers given and the feedback provided by other students. When students completed one of these tasks, points were awarded immediately. In contrast, students were not made aware of the algorithm for the awarding of badges, but were awarded badges as visual symbols of accomplishment when they reached the undisclosed achievement levels, thereby supporting the competence component of self-determination theory. Examples of the websites as seen by the students are shown in Appendix.

### *2.3 Measurement*

Students' gamification activities were measured. Whenever students created their own questions regarding lab materials and answered the questions created by other students, they earned points. The specific point algorithm is shown in Table 3. Students' scores were then used to determine level and ranking for competition between the students. More detailed information on the gamification websites is available in a previous study [7].

While there are various instruments that can allow for the operationalization of intrinsic and extrinsic motivation, amotivation is assessed solely by the AMS [50]. Whereas the original AMS was designed as a global measure of academic motivation, it was modified to the HF course context in this study. The AMS consists of seven subscales, each of which is assessed with four items on a seven-point Likert scale on a continuum from 1, where 1 = does not correspond at all, to 7, where 7 = corresponds exactly: IM–to know, IM–toward accomplishment, IM – to experience stimulation, EM – identified, EM – introjected, EM – external regulation and amotivation. The Original AMS showed good reliabilities (Cronbach's alpha ranging from 0.63 to 0.86 for different subscales), validity (Normal Fit Index = 0.93) and repeatability (one-month test-retest correlation was $r = 0.79$) [45]. In this study, we used the variables of autonomous motivation (AM), controlled motivation (CM) and amotivation based on previous studies [33, 49, 50]. AM represents a measure of the amount of self-determined motivation, i.e., the motivation that came from within the student. AM was calculated by summing up the average scores on intrinsic motivation and identified regulation subscales of the AMS. CM is a measure of motivation that originated outside of the individual, meaning that it was determined by external factors or reasons. CM was calculated by summing up the average scores on introjected and external regulation subscales of the AMS.

Students' learning outcomes were measured based on the grades obtained in the course. Although Rovai et al. [52] argued that using grades to operationalize learning may not always provide the best results, grades give a more objective measure than self-reported measurements and are the most prevalent measure of cognitive learning outcomes [53, 54]. In this study, we used the general knowledge test score, midterm score and final exam score in order to normalize the grade. For the first phase, the normalized grade is the difference between the general knowledge test score and the midterm score, and for the second phase, the normalized grade is the difference between the general knowledge test score and the final exam score.

### *2.4 Data Analysis*

The Statistical Package for Social Sciences (SPSS) and Amos were used to perform all statistical analyses, including a two-sample t-test, paired two sample t-test and structural equation modeling. The two-sample t-test was used to compare data from

**Table 3.** Score algorithm in gamification systems

| Creating a question | Points | Answering a question | Points |
|---|---|---|---|
| Basic score | 300 | Correct answer | 200 |
| Feedback score | 0 or 200 | Wrong answer | 0 |
| Quality score | Up to 500 | | |

the two different semesters in terms of gamification activity and learning outcome. The paired two-sample t-test was used to evaluate hypothesis H1. Finally, H2 to H8 were tested using SEM.

## 3. Results

We compared students' exam scores (general knowledge, midterm and final) and gamification activities, including the number of questions authored, the number of answers submitted, and the number of distinct days of activity between two semesters (2016 Fall and 2017 Fall). For both semesters, all conditions of the experiment and its setting remained the same, except for the instructor and students. The results are shown in Table 4 and Table 5. There is no significant difference in students' general knowledge score between two semesters ($t(81) = 1.184$, $p = 0.281$). For students' learning outcomes such as midterm and final exam score, there is no significant difference between two semesters (Midterm: $t(81) = -1.497$, $p = 0.146$, Final $t(81) = -0.776$, $p = 0.440$). For gamification activities, even though there is a significant difference in the difficulty of questions during the second phase of each semester ($t(96) = -4.90$, $p = < 0.01$), overall there was no significant difference in main activities, such as the number of questions and answers, between the two semesters. Thus, we combined all data from both semesters for further hypothesis testing.

A paired t-test was conducted on all of motivational measures, which were collected during the 7th week (Time 1) and 15th week (Time 2) of the semester. Table 6 shows the mean and standard deviation for IM, CM and AM. In general, students' levels of motivation did not decrease over time. Specifically, students' IM showed a significant increase, and their CM showed no difference. How-

**Table 4.** Students' exam scores from both semesters

| Grade | Semester | N | Mean (SD) | P Value |
|---|---|---|---|---|
| General Knowledge Test Score | 2016 | 24 | 34.58 (11.41) | 0.281 |
| | 2017 | 59 | 31.69 (9.50) | |
| Midterm Exam Score | 2016 | 24 | 79.08 (10.89) | 0.146 |
| | 2017 | 59 | 82.59 (5.72) | |
| Final Exam Score | 2016 | 39 | 82.72 (7.92) | 0.440 |
| | 2017 | 59 | 87.33 (5.69) | |

**Table 5.** Summary of gamification activities between two groups for both phases

| Activity | Year | 1st Phase | | | | 2nd Phase | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | Mean (SD) | P Value | d | N | Mean (SD) | P Value | d |
| **Number of Questions** | 2016 | 24 | 7.46 (6.58) | 0.385 | 0.25 | 39 | 7.56 (7.25) | 0.582 | 0.11 |
| | 2017 | 59 | 6.24 (2.44) | | | 59 | 8.25 (5.11) | | |
| Quality of Questions | 2016 | 24 | 3.00 (1.06) | 0.337 | 0.26 | 39 | 3.15 (0.35) | 0.076† | 0.36 |
| | 2017 | 59 | 3.22 (0.56) | | | 59 | 3.01 (0.41) | | |
| Difficulty of Questions | 2016 | 24 | 1.64 (0.53) | 0.217 | 0.34 | 39 | 1.51 (0.27) | < 0.01** | 1.02 |
| | 2017 | 59 | 1.79 (0.32) | | | 59 | 1.80 (0.30) | | |
| Number of Followers | 2016 | 24 | 2.04 (3.25) | 0.542 | 0.14 | 39 | 3.82 (6.00) | 0.117 | 0.35 |
| | 2017 | 59 | 2.46 (2.61) | | | 59 | 2.20 (2.43) | | |
| **Number of Answers** | 2016 | 24 | 36.96 (23.83) | 0.170 | 0.30 | 39 | 54.21 (43.97) | 0.848 | 0.04 |
| | 2017 | 59 | 46.47 (37.11) | | | 59 | 56.15 (52.23) | | |
| Number of Comments | 2016 | 24 | 10.42 (12.49) | 0.528 | 0.14 | 39 | 7.56 (8.82) | 0.459 | 0.16 |
| | 2017 | 59 | 8.90 (8.66) | | | 59 | 6.41 (4.95) | | |
| **Number of Distinct Days** | 2016 | 24 | 17.63 (4.14) | 0.074† | 0.38 | 39 | 20.18 (4.58) | 0.495 | 0.15 |
| | 2017 | 59 | 15.31 (7.41) | | | 59 | 21.02 (6.67) | | |
| **Number of Badges** | 2016 | 24 | 8.75 (3.55) | 0.458 | 0.18 | 39 | 10.18 (3.53) | 0.348 | 0.2 |
| | 2017 | 59 | 8.07 (3.86) | | | 59 | 9.36 (4.63) | | |

† p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001.

**Table 6.** Mean and standard deviation for AM, CM and amotivation

| Motivation | Time 1 (week 7) | | Time 2 (week 15) | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| AM | 4.81 | 0.89 | 4.98 | 1.07 |
| CM | 5.20 | 0.71 | 5.31 | 0.83 |
| Amotivation | 3.27 | 1.51 | 2.94 | 1.50 |

**Table 7.** Reliability testing

| Variables | Cronbach's alpha |
|---|---|
| IM to know | 0.767 |
| IM accomplishment | 0.769 |
| IM stimulation | 0.768 |
| EM-identified regulation | 0.750 |
| EM-introjected regulation | 0.752 |
| EM-external regulation | 0.773 |
| Amotivation | 0.933 |
| AM | 0.751 |
| CM | 0.753 |

IM (intrinsic motivation), EM (extrinsic motivation), AM (autonomous motivation), CM (controlled motivation).

ever, students' AM significantly declined over the course of the semester.

### 3.1 Structured Model Evaluation

To test H2 through H8, hypothesis testing was conducted using structural equation modeling (SEM). The reliabilities of dimensions in this study (Table 7) ranged from 0.75 to 0.933, which is higher than the widely accepted 0.7 threshold for each dimension of Cronbach's alpha. The average variance extracted (AVE) ranged between 0.61 and 0.7, and were always larger than 0.5. This study, therefore, satisfies reliability and validity conditions.

The correlations between the different variables were as follows (see Table 8): Amotivation was significantly negatively correlated with all other variables. AM and CM were significantly positively correlated, which was expected as it had been observed in earlier studies [51]. Learning outcome and gamification were significantly positively correlated with AM and CM.

The result of structural equation model analyses is depicted in Fig. 2 and is an acceptable fit to the data: $\chi^2$(df = 18, N = 166) = 25.738, p = 0.106, GFI = 0.971, RMSEA = 0.049, CFI = 0.992, AGFI = 0.926 and SRMR = 0.042. However, the paths from both CM and amotivation to learning outcome were not significant. The estimated model appears in Fig. 2 with path coefficients included. The total variance R2 values for AM, CM, amotivation and learning outcome were 21.8, 7.5, 10, and 39% of the variance, respectively. Based on the structural model analysis, the results showed that gamification activity had a significant positive influence on AM ($\beta$ = 0.467, p < 0.001) and CM ($\beta$ = 0.273, p < 0.001) and negative influence on amotivation ($\beta$ = –0.317, p < 0.001). Structural model analysis also found that gamification activity had a significant positive influence on learning outcome ($\beta$ = 0.431, p < 0.001). Finally, AM had a significant positive influence on learning outcome ($\beta$ = 0.295, p < 0.01).

## 4. Discussion

This study was designed to test (1) a hypothesis that gamification can maintain student motivation over the course of the semester and (2) a hypothesized model in which gamification would positively affect intrinsic and extrinsic motivation, but negatively affect amotivation, thereby leading to a positive effect on academic performance. Overall, the results of data analysis demonstrate support for all hypotheses.

Regarding H1, previous studies showed that students' levels of motivation decreased over time [55–57]. For example, Zusho et al. [55] assessed motivation at three points in time over a semester for 458 students enrolled in introductory college chemistry classes. They found a decline in students' motivation in such aspects as self-efficacy, task value and goal of the performance. Nilsson & Warrén Stomberg [56] found a similar trend of decreased student motivation for nursing students in Sweden. However, our results showed that stu-

**Table 8.** The correlations between the different variables

| | Amotivation | AM | CM | Learning Outcome |
|---|---|---|---|---|
| AM | –0.439*** | | | |
| CM | –0.201** | 0.614*** | | |
| Learning Outcome | –0.326*** | 0.439*** | 0.238** | |
| Gamification | –0.317*** | 0.438*** | 0.252** | 0.57*** |

AM (autonomous motivation), CM (controlled motivation). † p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001.

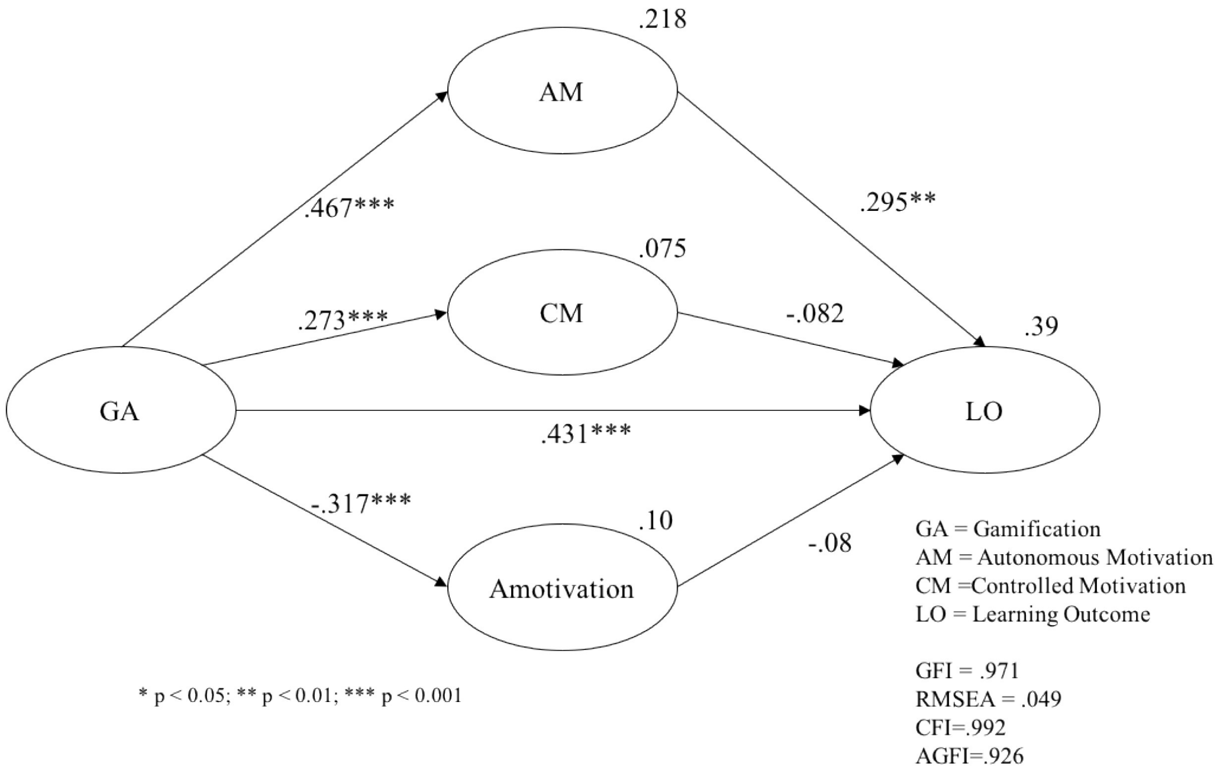


**Fig. 2.** Structural equation model depicting relationship between gamification, motivation, and performance.

dents' motivations, measured as intrinsic and extrinsic motivation, did not decrease over the time, which implies that gamification plays a role in mediating factors related to maintaining students' motivation throughout the semester. Furthermore, students' amotivation significantly decreased over time. Theoretically, those with high levels of amotivation would be more likely to engage in negative behaviors, as they would be more likely to be disengaged and unattached to learning [58]. Thus, we suggest that applying gamification as a supporting tool in learning environments may change student behavior by changing amotivation to extrinsic or intrinsic motivation.

Regarding H2 through H8, results indicate that gamification engagement is positively associated with autonomous and controlled motivations as well as student performance, but it is negatively associated with amotivation. It is expected that gamification engagement is positively related to controlled motivation since our gamification system was reward-based, awarding students points or badges whenever they completed a predefined task. For example, whenever students created their own question or answered the questions created by other classmates, they received points, which were then used to calculate ranking. This result is consistent with those of previous studies on gamification in education [11, 59–61]. The relationship between gamification engagement and autonomous motivation is an unexpected result because our gamification system is reward-based, and previous studies have found that reward-based gamification diminishes students' intrinsic motivation based on CET. For this reason, with respect to H2, we expected that our gamification system would not impact students' autonomous motivation, but results showed that gamification has a positive effect on student motivation, maintaining motivation over the course of the semester. Our results thus demonstrate that reward-based gamification does not always diminish students' intrinsic motivation in the way that previous studies suggest. One possible explanation for this is that even though students started to participate in gamification activity due to the reward, (a decision related to controlled motivation), extrinsic motivation was converted into intrinsic motivation by feeling enjoyment from some game element such as badge, points or feedback during the gamification activity. Thus, we expect that reward-based gamification can promote an increase not only in students' extrinsic motivation, but also in their intrinsic motivation, resulting in a change in student behavior. Autonomous motivation also had a significant impact on student learning outcome. This result echoes previous studies that found intrinsic motivation to be positively related to students' academic achievement [35, 62, 63]. This is because if the students feel competent when learning, they will experience an increase in autonomous academic motivation that will, in turn, help them to achieve higher scores on exams. However, there is a negative relationship between controlled motivation and learning outcomes, as shown in previous research by Vansteenkiste et al. [64]. Finally, we posit that gamification engagement is positively associated with student learning outcome. Even though there were mixed results regarding the effect of gamification on learning outcomes in the literature, this study provides empirical evidence that supports a positive relationship between gamification engagement and student learning outcome.

## 5. Conclusion

In summary, a key result of the current study is that gamification can be used as a supporting tool in education to maintain students' motivation over time, resulting in improved learning outcomes. Furthermore, we identified empirical evidence that even reward-based gamification can increase students' intrinsic motivation, which, in turn, suggests that reward-based gamification makes it possible to change student behavior. As a result, we believe our study is a valuable first step in this direction and may serve as a blueprint for future studies. We expect that these results will inform instructors who are interested in gamifying their courses and will help them in deciding how to develop gamification for use in their specific contexts.

However, this study does have limitations, and further research will be required. The first limitation of this study is that the effects of individual game elements on students' motivation were not determined. More empirical research is necessary to determine why particular game elements act as extrinsic or intrinsic motivators in a given context and how this in turn shapes students' behavior. The second limitation is that this study relied on questionnaires asking users how motivating or enjoyable their gamification experience was. We did not track students' emotions or experience in relation to gamification through such psychological and psychophysiological measurements as the galvanic skin response (GSR), the heart rate response (HRV), facial EMG, or EEG. While the questionnaire method allows for easy implementation, it is also subject to the following considerable limitations: (1) people may lie or bend the truth due to social desirability, (2) collecting data during a task disturbs the task, and (3) data collected retrospectively may differ from data collected concurrently. To avoid these flaws, objective metrics need to be collected in real time, where the metrics correlate to one or more emotion measurements.

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## Appendix *(next 3 pages)*

## Appendix

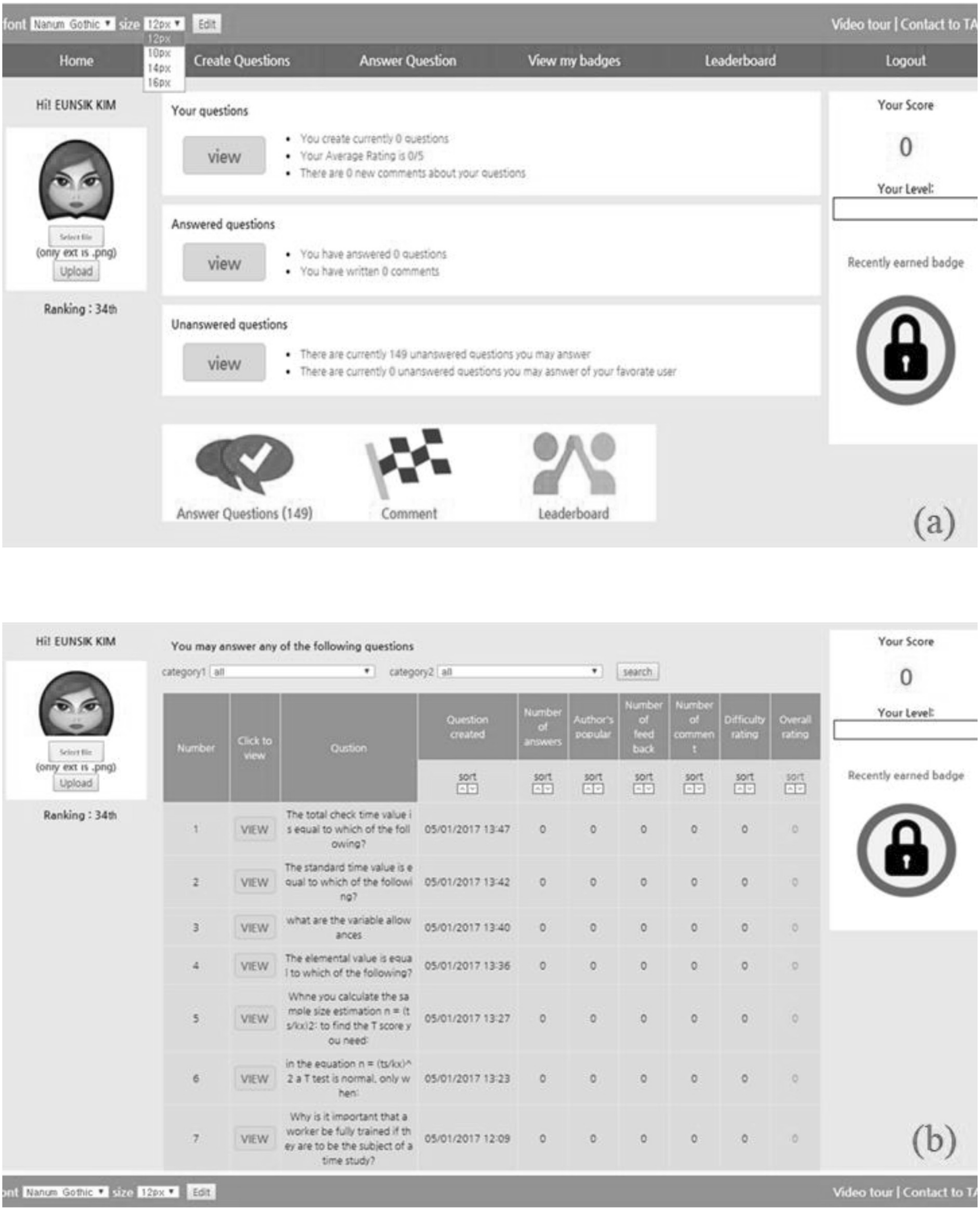


**Fig. A.** Sample pages from gamification system: (a) main page, (b) question list page, (c) question page, (d) question evaluation page, (e) badge page, and (f) leaderboard page.

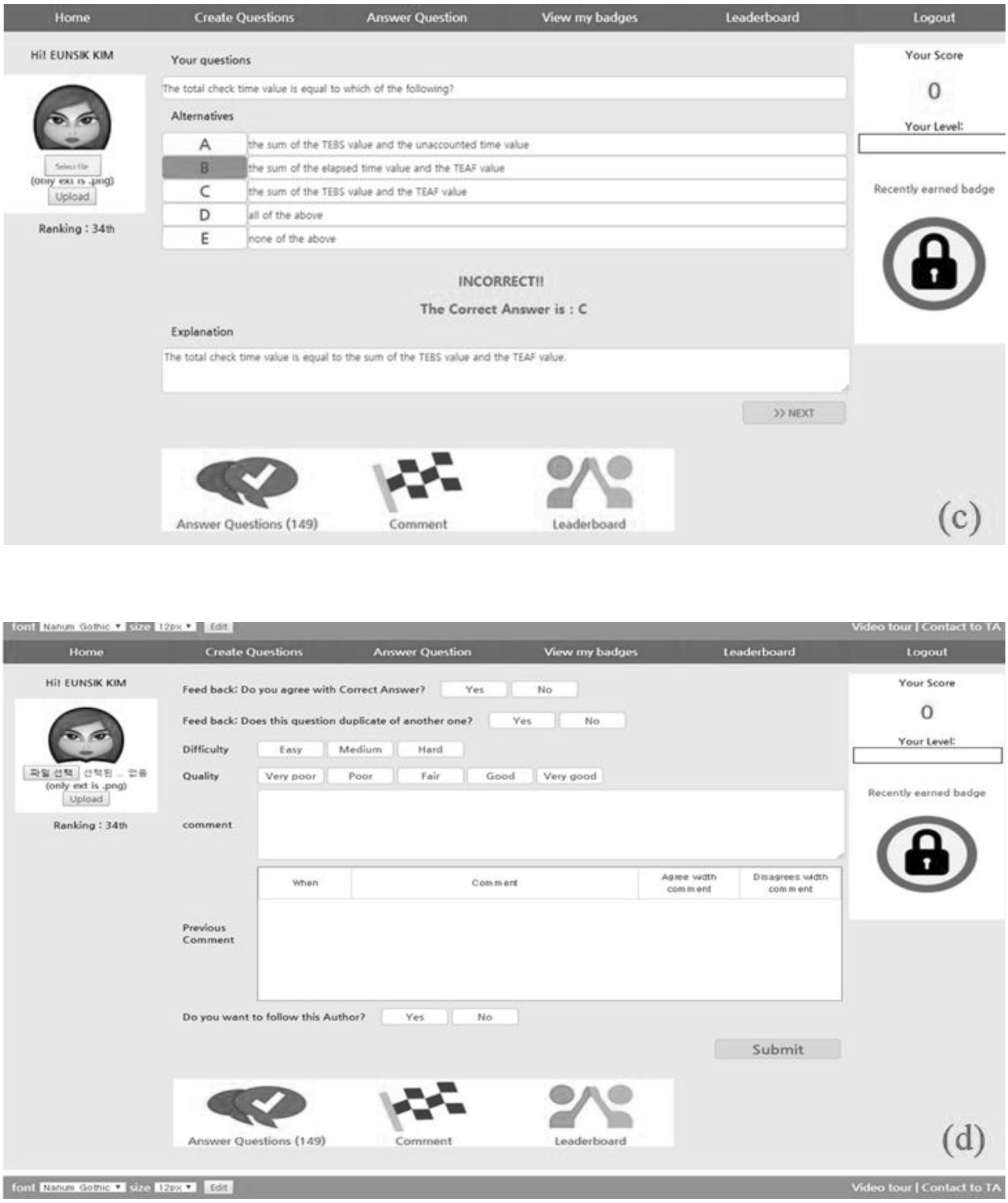


**Fig. A** Sample pages from gamification system: (a) main page, (b) question list page, (c) question page, (d) question evaluation page, (e) badge page, and (f) leaderboard page (*Continued*).


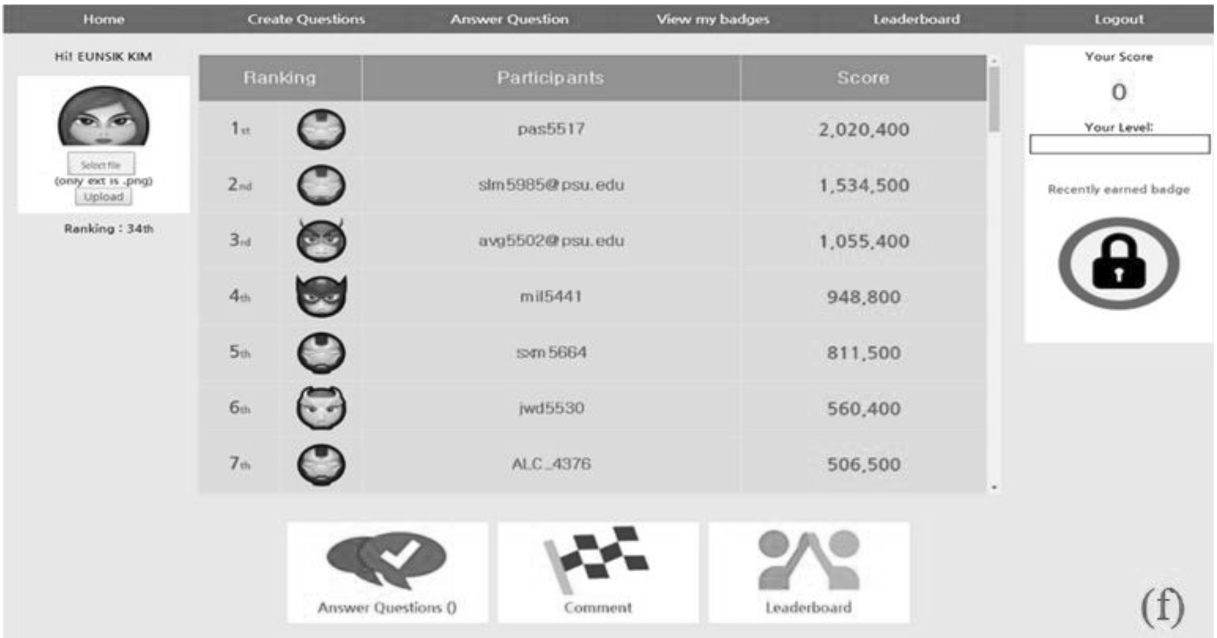


**Fig. A** Sample pages from gamification system: (a) main page, (b) question list page, (c) question page, (d) question evaluation page, (e) badge page, and (f) leaderboard page (*Continued*).