Computers & Education 142 (2019) 103643

Contents lists available at ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

GAMESIT: A gamified system for information technology training

Juneyoung Park[a], De Liu[b,*], Mun Y. Yi[a], Radhika Santhanam[c]

[a] Korea Advanced Institute of Science and Technology (KAIST), South Korea
[b] Information and Decision Sciences Department, Carlson School of Management, University of Minnesota, United States
[c] MIS Division, Price College of Business, University of Oklahoma, United States

ARTICLE INFO

Keywords:
Gamification
Training
Design science
Game elements
Laboratory experiment

ABSTRACT

Gamified learning systems can enhance both learning outcomes and engagement, but research findings on the effectiveness of such systems are mixed, and there is inadequate attention to theory-grounded designs of gamified learning systems. We address these gaps by conducting a theory-grounded design, development, and evaluation of a gamified e-training system for technology learning. Called GAMESIT, this e-training system has an added gamification layer. Drawing upon Malone's theory of intrinsically motivating instruction, we choose and design gamification elements (e.g., levels, avatar evolution, and distinct visuals) to create appropriate motivational drivers, namely, challenge, curiosity, and fantasy, for learning tasks. We follow a design science framework to iteratively develop GAMESIT and evaluate its effectiveness. In a laboratory experiment, participants using GAMESIT, when compared to those using the non-gamified e-training system, showed improvement in learning outcomes, measured as learners' knowledge comprehension and task performance, and higher engagement, captured through learners' cognitive effort.

1. Introduction

Due to the potential of gamification to positively influence user behaviors, organizations are gamifying a variety of applications, with technology-mediated training (i.e., e-training) being a popular one (Barata, Gama, Jorge, & Goncalves, 2017). In fact, many educational organizations are using gamification for training employees, as well as their students (Kuo & Chuang, 2016). For example, at the University of Notre Dame, the information technology (IT) division gamified its Google Apps training using a Jedi-themed gamification design.[1] Every time an IT support person successfully passed Google Apps knowledge tests, his/her Jedi status would move up the Jedi ladder: Padawan, Jedi Knight, and finally Yoda. This gamification approach was so successful that many other professionals in the university joined the training program. There are many such success stories, but several reports indicate that attempts to gamify systems do not always lead to successes, mostly because of poor design approaches adopted in organizations (Hamari, Koivisto, & Sarsa, 2014). Specifically, research on gamified designs for learning indicates a lack of consistent findings on the effectiveness of gamified designs and call for more systematic designs and holistic evaluations (Jagust, Boticki, & So, 2018). A recent review on gamified learning reveals a significant number of null or mixed results (Majuri, Koivisto, & Hamari, 2018). One common drawback among existing gamified learning studies is their reliance on existing gamification systems that offer prepackaged game elements (e.g., points, badges, and leaderboards). As a result, researchers have called for a "research through design" approach that allows one to investigate a fuller range of gamification design options (Rapp, Hopfgartner, Hamari, Linehan, & Cena, 2019).

* Corresponding author.
E-mail addresses: j.park89@kaist.ac.kr (J. Park), deliu@umn.edu (D. Liu), munyi@kaist.ac.kr (M.Y. Yi), Radhika@ou.edu (R. Santhanam).

[1] https://er.educause.edu/articles/2015/7/a-jedi-story-gamification-at-work.

https://doi.org/10.1016/j.compedu.2019.103643
Received 8 December 2018; Received in revised form 26 July 2019; Accepted 28 July 2019
Available online 30 July 2019
0360-1315/

To address the existing conflicting findings and examine the efficacy of gamified designs for training and learning [2] without the limitation of pre-existing game elements, we adopt the approach of designing and developing a gamified training system from the ground up with carefully chosen game elements that are based on established theories, then evaluating the effectiveness of the e-training system via controlled experiments. This approach, suggested by a few recent studies (Jagust et al., 2018; Kuo & Chuang, 2016), can provide several benefits: first, it allows researchers to incorporate relevant theories and design principles to avoid evaluating a poorly designed gamified system. Second, it gives researchers better control of the system's design (e.g., with and without gamification), which is crucial to the evaluation of the effectiveness of gamification. Finally, the very process of designing, developing, and evaluating a gamified system provides insights and lessons on how to design gamified systems for learning.

Therefore, we designed, developed, and evaluated a gamified system for IT training that we refer to as GAMESIT. GAMESIT adds a gamification layer to an e-training system where people learn at their own pace by interacting with an online technology platform. Because of a persistent problem of learner disengagement and high drop-out rates, gamification is proposed as a way to improve e-training outcomes (Allen & Seaman, 2011). IT training is a good domain for evaluating the effectiveness of gamified learning designs for several reasons. First, it is a practical and important domain, where many organizations make regular and large investments (Green & McGill, 2011). Second, gamified IT training as a relatively new solution has a low level of maturity and yields inconsistent results (Gregor & Hevner, 2013).[3] The extant studies of gamified learning systems focus primarily on instructor-led or online courses with scant attention paid to self-guided e-training sites, which is a primary mode of employee training in many learning organizations (Dicheva, Dichev, Agre, & Angelova, 2015). Finally, we can leverage a cumulative body of IT training and learning research for developing and evaluating a theory-driven gamification design for IT training (Santhanam, Yi, Sasidharan, & Park, 2013; Yi & Davis, 2003).

In designing and developing GAMESIT, we specifically draw from the theory of intrinsically motivating instruction to identify three most relevant motivational drivers - curiosity, challenge, and fantasy - for engaging people in learning activities (Jagust et al., 2018; Malone, 1981; Malone & Lepper, 1987). We then identify gamification design elements that can generate these motivational drivers. Using an iterative design and test method, we add these gamification design elements to a non-gamified e-training system to form GAMESIT. Finally, we use a laboratory experiment to test the relative effectiveness of GAMESIT against the non-gamified e-training system on two types of outcomes: 1) learning outcomes (also referred as instrumental outcomes), which are captured by knowledge comprehension and task performance and 2) engagement (also referred as experiential outcomes) which are captured by cognitive effort (Ding, Kim, & Orey, 2017; Santhanam et al., 2013).

Our empirical findings show that GAMESIT improves both learning and engagement. On learning outcomes, participants using GAMESIT, relative to those using the non-gamified e-training system, demonstrated increased knowledge comprehension and task performance. On engagement, participants using GAMESIT exhibited higher cognitive effort, indicating more engagement in the learning process. We thus address the conflicting results in gamified learning systems by demonstrating that an appropriate theory-driven, design-science-guided approach to gamification design can help develop effective gamified learning systems.

In the next section, we discuss the related research, followed by the description of the design framework for GAMESIT, its design, development, and evaluation. We then present findings from the empirical evaluation of GAMESIT and discuss their implications.

2. Related work

The general idea of using game elements to support learning has been used earlier in simulation games, through which users learn from modeled real-world scenarios, and in game-based learning (GBL) where users' playing and learning activities are fully integrated (Cronan, Léger, Robert, Babin, & Charland, 2012). Gamification is another way to leverage game design elements for learning, with a few notable distinctions. First, a gamified e-training system is an e-training system and not a full-fledged game. Second, while the earlier GBL approach seeks to integrate learning activities into full-fledged games (Glover, 2013), gamification designs call for adding a game layer to full-fledged learning systems, providing more design flexibility and requiring fewer resources (Santhanam et al., 2013). For recent reviews of gamification research, we refer readers to (Nacke & Deterding, 2017; Rapp et al., 2019; Seaborn & Fels, 2015).

Several studies have evaluated gamified learning systems in contexts including classrooms and online learning (Landers & Armstrong, 2017; Seaborn & Fels, 2015). We identify a few sample studies relevant to ours and organize them in Table 1 to facilitate understanding of common themes. Among these studies, most leverage commercially available gamification plug-ins for learning platforms such as Moodle or Blackboard (de-Marcos, Garcia-Lopez, & Garcia-Cabot, 2016; Hew, Huang, Chu, & Chiu, 2016; Huang & Hew, 2015); few build customized gamification applications (Barata et al., 2017; Dominguez et al., 2013; Kuo & Chuang, 2016; van Roy & Zaman, 2018). Nearly all studies examine the gamification of an instructor-led college course with the exception of Kuo and Chuang (Kuo & Chuang, 2016), which examines a gamified online platform for knowledge dissemination. Among the game elements studied, the most popular ones include leaderboards (de-Marcos et al., 2016; Dominguez et al., 2013; Hanus & Fox, 2015; Hew et al., 2016; Huang & Hew, 2015; Kuo & Chuang, 2016) and badges (Barata et al., 2017; de-Marcos et al., 2016; Dominguez et al., 2013; Hanus & Fox, 2015; Hew et al., 2016; Kuo & Chuang, 2016; Kyewski & Krämer, 2018). Collectively, these studies paint a pessimistic

[2] Training and learning are closely related terms, with the former used more often in organizational contexts. In this paper, we use the two terms interchangeably, but note that we primarily focus on organizational contexts where the goal is to help employees develop the skills needed to perform specific tasks.

[3] Please note that gamified learning systems should not be confused with game-based learning systems, which require full-fledged games.

Table 1
Some recent studies on the effects of gamification in E-learning/online learning contexts.

	Gamification Design	Cited Theory	Research Design	Context	Outcomes
Dominguez et al. (2013)	Blackboard with custom plug-ins (achievement, badge, leaderboard)	N/A	Non-randomized controlled study	An introductory undergraduate course on office software	Gamified group did better on practical applications but worse on understanding of concepts, written exams, and participation
Huang and Hew (2015)	Moodle with a gamification plug-in (leaderboard, point)	Self-determination theory	Non-randomized controlled study	A master-level research methods course focusing on SPSS	Gamified group is more engaged in online/ learning activities but shows no difference in quiz scores
(de-Marcos et al., 2016)	Moodle with a gamification plug-in (challenge, badge, leaderboard)	N/A	Non-randomized controlled study	An introductory undergraduate course on office software	Experiment groups generally did better in practical applications, but worse in final exams
Hew et al. (2016)	Moodle with a gamification plugin (badge, point, leader boards)	Self-determination theory	Non-randomized controlled study	A graduate questionnaire design course	Gamified group did more forum posting. No significant difference in test scores
Barata et al. (2017)	Moodle with custom-built gamification (points, badge, skill-tree, group achievement)	Self-determination theory	Longitudinal uncontrolled field study	A master-level multimedia content production course	Classification of users based on their reactions to the gamified learning system
Hanus and Fox (2015)	Gamified course with researcher-designed badges and a leaderboard	Self-determination theory & social comparison theory	Non-randomized controlled study	A college-level communication course	Students in the gamified course showed less motivation, satisfaction, empowerment, and lower final exam scores
Kyewski and Krämer (2018)	Moodle with two different badge designs (social & non-social)	Self-determination theory	Randomized controlled study	An online seminar at a German university	Providing badges did not significantly increase student motivation and activity on the online learning platform.
Kuo and Chuang (2016)	Gamified online platform for academic knowledge dissemination (point, badge, leaderboard, mini-games, gift rewards)	NA	Analysis of archival data	A gamified online website for a university in Taiwan	Gamification creates engagement but the choice of gamification elements is key.
van Roy and Zaman (2018)	Gamified Google + communities (challenge, badge, and group competition)	Self-determination theory	Survey	A graduate course in Belgian University	Gamification has a motivational effect when studied over time, and game elements have to be designed carefully for the target group.

Fig. 1. Theoretical foundations for gamified E-training design and development.

picture of the effect of gamification on exam scores: three studies find a negative impact (de-Marcos et al., 2016; Dominguez et al., 2013; Hanus & Fox, 2015) and two show an insignificant impact (Hew et al., 2016; Huang & Hew, 2015), although few studies suggest that gamification may increase the practical application of knowledge and skill (de-Marcos et al., 2016; Dominguez et al., 2013). Several studies find a positive effect of gamification on motivation or engagement (Hew et al., 2016; Huang & Hew, 2015; Kuo & Chuang, 2016; van Roy & Zaman, 2018), though researchers point out that the choice of game elements is key for engagement (Kuo & Chuang, 2016; van Roy & Zaman, 2018). Still, some studies find a negative effect or no effect on engagement, while recent reviews caution that even when quantitative outcomes are positively oriented, in-depth qualitative analysis suggests that results among users vary considerably (Hanus & Fox, 2015; Kuo & Chuang, 2016; Majuri et al., 2018).

Existing research has used several theoretical perspectives or design frameworks to guide gamification design. Self-determination theory (SDT) has been applied many times to understand gamification in learning (Barata et al., 2017; Hanus & Fox, 2015; Hew et al., 2016; Huang & Hew, 2015; Kyewski & Krämer, 2018). SDT identifies competence, autonomy, and relatedness as three main sources of intrinsic motivation, providing an important theoretical foundation for understanding how gamification designs may affect user motivations (Deci & Ryan, 2000). In addition, researchers have also long explored games as a source of design inspiration from the perspective of funology (Blythe, Overbeeke, Monk, & Wright, 2005) and persuasive technology (Fogg, 2002). Yet another set of papers approach gamification design by cataloging gamification elements (Robinson & Bellotti, 2013), design principles (Liu, Santhanam, & Webster, 2017), and reward types (Rapp, 2017).

Our study differs from existing research in several ways. First, we draw upon Malone's theory of intrinsically motivating instruction (Malone, 1981), which provides us design guidelines in terms of choice of game elements relevant to a learning context. Second, our design does not use badges or leaderboards that are frequently used in existing designs (Majuri et al., 2018), but we highlight elements that provide for motivational drivers outlined in the theory of intrinsically motivating instruction, such as avatar evolution and fantasy-inducing visual feedbacks. Third, e-training represents a different context from the traditional course settings: E-training is usually more voluntary and not instructor-led. Fourth, we follow a design science framework to emphasize theory-based design. Finally, we add to a small literature that employs rigorous randomized controlled trials to evaluate the effects of gamification.

We note that gamification implementations are subject to various risks, potentially rendering them ineffective or even harmful. Recent studies show that by adding game elements such as points, badges, and leaderboards without a more careful design, we could create “pointification” situations where users just collect points and rewards, which result in voiding the user experience and users “gaming the system” (Rapp, 2015; Robertson, 2010). Furthermore, research in education as well as recent gamification studies show that extrinsic motivators such as leaderboards and badges can potentially undermine intrinsic motivation and learning (Deci, Koestner, & Ryan, 1999; Hanus & Fox, 2015). Recent reviews of gamification designs suggest the need to go beyond simple applications of points/badges/leaderboards and to focus on theory-guided gamification designs that align better between gamification affordances and existing problems (Nacke & Deterding, 2017; Rapp et al., 2019).

3. A framework for designing and developing a gamified E-training system

In the language of design science (Hevner, March, Park, & Ram, 2004), the design and development of GAMESIT is an iterative search process to discover a new IT solution (i.e., a gamification layer).

In designing GAMESIT, we primarily draw upon three research traditions: gamification, training, and design science (Fig. 1). The extensive research on technology training provides us theoretical bases for identifying appropriate gamification design elements for our learning contexts (Yi & Davis, 2003). It also helps us identify relevant training outcomes. Gamification research provides a

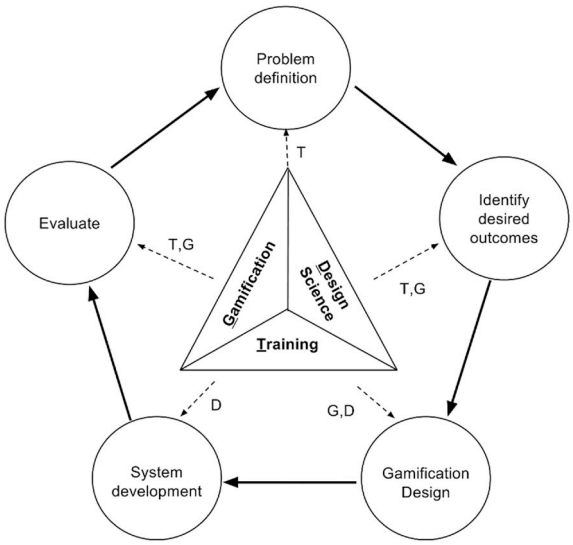


Fig. 2. A theory-driven gamification lifecycle.

repertoire of gamification design elements and focuses our attention on making non-game activities engaging (Liu et al., 2017). Finally, the design science framework provides guidelines on how to iteratively build and evaluate a system, and prescribes methods, such as usability analysis and agile development, for robust system development.

The research traditions identified above inform our gamification lifecycle (Fig. 2). Adapted from Peffers, Tuunanen, Rothenberger, and Chatterjee (2007)'s design science framework, this gamification lifecycle includes five iterative stages: problem definition, identification of desirable outcomes, gamification design, system development, and evaluation. Each stage is guided by one or more of the aforementioned research traditions: Training (T), Gamification (G), and Design Science (D). This framework allows us to arrive at a theory-driven, formally represented, and empirically evaluated gamified e-training artifact (Hevner et al., 2004).[4] We discuss the first two stages below and then dedicate separate sections for the remaining three stages.

3.1. Problem definition

Research and practice in IT training highlight a key problem in e-training systems - a lack of engagement from users. This problem could potentially be alleviated by gamification designs (Santhanam, Sasidharan, & Webster, 2008). Therefore, the specific problem addressed in this research is the following: *How do we systematically design and develop a theory-driven gamified e-training system that can improve learning outcomes and enhance engagement in learning?*

3.2. Desired outcomes

As suggested in recent research (Liu et al., 2017), a good gamification design must simultaneously result in learning outcomes and engagement. Typical learning outcomes of an e-training program include knowledge comprehension, consisting of declarative and procedural knowledge, and task performance, indicating users' ability to complete a task using the acquired knowledge (Santhanam & Sein, 1994; Yi & Davis, 2003).

As for engagement, educational researchers suggest that it can be defined from behavioral, emotional or cognitive perspectives. Because the goal of this study is to motivate deeper cognitive involvement in the learning tasks rather than mere participation, we focus on the cognitive engagement, which Fredricks et al. (Fredricks, Blumenfeld, & Paris, 2004) describe as “thoughtfulness and willingness to exert the effort necessary to comprehend complex ideas and master difficult skills.” Specifically, we chose *cognitive effort*, which indicates users' attention and involvement in the learning process, as our measure of cognitive engagement. Cognitive effort is an important metric of user attention and engagement in prior studies of learning and problem solving, where knowledge and skill acquisition is a key goal (Kanfer & Ackerman, 1989; Yeo & Neal, 2008).

[4] Though our design process is based on Peffers et al. (2007)'s general guidelines, it is remarkably consistent with the suggested design process for gamification by Morschheuser, Hassan, Werder, and Hamari (2018). For example, we began with a definition of design objectives and requirements based on in-depth understanding of users' motivations, needs, and learning context. We followed a user-centered iterative design and test method, where we continuously developed and revised our prototype based on user feedback. We also developed clear metrics ahead of time and conducted a controlled study to determine the differences between a gamified and a non-gamified version of our system. However, because our system was for research purposes only, we were unable to test it in a production environment as suggested by Morschheuser et al. (2018).

3.3. Theory-driven gamification design

To fit gamification elements to the learning task, we specifically draw upon Malone's theory of intrinsically motivating instruction that has direct implications on which game elements and mechanics can serve as "motivational drivers" in learning activities. By studying computer games, Malone (1981) identifies three categories of motivational drivers that are particularly relevant to learning.[5] First, offering a sense of *challenge* could intrinsically motivate a learner. Second, evoking learners' sense of *curiosity* (e.g., through novel sounds and puzzles) would engage learners. Third, *fantasies* that are emotionally appealing, could also engage users in learning activities.

We chose Malone's theory of intrinsically motivating instruction because it has two unique advantages compared with other theoretical perspectives for our design goals. First, Malone's theory was developed from observing children playing a variety of computer games such as Star Trek, Hangman, and Breakout. Consequently, it is particularly suitable for guiding the choice of game elements. It not only points out the important motivational drivers, but also provides insights on how to optimally design them (which we will discuss next). Second, Malone's theory is intended for the design of instruction systems. Though Malone may not have anticipated its use in gamification settings, the theory has abstracted motivational drivers at such a fundamental level that it can be applied to both game-based learning and gamification.

3.3.1. Challenge

Challenge offers individuals an opportunity to develop their competence and feelings of efficacy in dealing with their environment (Csikszentmihalyi & Czikszentmihalyi, 1975; Liu, Li, & Santhanam, 2013; Reeve & Deci, 1996). Malone and his colleagues (Malone, 1981; Malone & Lepper, 1987) notice that proximal goals are more motivating than distal ones, and hierarchical goals that simultaneously provide proximal and distal goals are especially motivating. Second, there must be *uncertainty* in the outcomes for an activity to be challenging. There are different ways to increase uncertainty in outcomes, e.g., by providing variable difficulty levels and multiple levels of goals, withholding information from users, and adding randomness (Malone & Lepper, 1987). Third, *performance feedback* is required for providing a continued challenge. A challenging environment should provide frequent, clear, and constructive performance feedback (Csikszentmihalyi & Czikszentmihalyi, 1975). Finally, challenges are intrinsically motivating because they engage learners' sense of *self-efficacy*, which refers to a belief in one's ability to successfully complete the given task. Challenges offer an opportunity to enhance their self-efficacy, which is correlated with enhanced learning outcomes (Bandura, 1997; Compeau, Gravill, Haggerty, & Kelley, 2006).

To create challenges in a gamified system, many game design elements can be applied. For example, in digital games, players often need to overcome a series of "enemies" with increasing difficulty, providing them variable challenges. Game designers often set up the challenges hierarchically using points, missions, and levels so that players have both immediate goals (e.g., earning points) and long-term goals (e.g. reaching the highest level). Consistent with Malone's theory and recent work in the educational domain (Malone, 1981; van Roy & Zaman, 2018), challenges should be designed with uncertainty outcomes, so that players must strive to overcome them.

3.3.2. Curiosity

Curiosity is another important motivational driver identified in Malone's theory of intrinsically motivating instruction. Curiosity includes cognitive and sensory curiosity. *Cognitive curiosity* can occur when a user perceives a gap in knowledge that motivates the user to engage in a learning process to complete their insufficient knowledge structure (Loewenstein, 1994; Malone & Lepper, 1987). This can be triggered by showing anomalies to users that suggest inconsistency and incompleteness in their knowledge. Game designers routinely use storytelling, puzzles, suspense, and novel characters and artifacts to evoke a player's cognitive curiosity. For example, offering puzzles after the learning content could be a great way to invoke a user's cognitive curiosity and motivate them to learn, or telling a story with an uncertain next turn. *Sensory curiosity* is triggered by sensory stimulations such as novel sounds, lights, or imagery during learning. Such sensory stimulation makes a user more alert and attentive, breaks the boredom and monotonicity, and draws attention to the learning task at hand (Clark & Paivio, 1991). Taken together, designs that promote a sense of curiosity can enhance both engagement (e.g., drawing attention and providing a vivid experience) and learning outcomes (e.g., highlighting and filling knowledge gaps).

3.3.3. Fantasy

Fantasy is yet another motivational driver that could be leveraged in learning contexts. Fantasy occurs when people make mental images of things that are not present to the senses or within the actual experience of the person involved (American Heritage Dictionary). For example, a video game may allow a person to fantasize of becoming a magician. Malone notes that fantasy can have two kinds of benefits. On the one hand, learners can satisfy their emotional needs of experiencing fantasies of power, fame, and fortune that may be unavailable in real life. On the other hand, fantasy can also have the benefits of simulation and modeling exercises, which allow them to gain knowledge and connections that have real-world applications. Research in training shows that the presentation of learning material in a fantasy context can result in increased engagement and learning outcomes (Cordova &

[5] Note that Malone and Lepper propose additional motivational drivers such as cooperation, competition, and interpersonal recognition, which are suitable for learning in interpersonal environments. Because we focus on single person learning environments, these are not relevant, and we do not discuss these in our research.

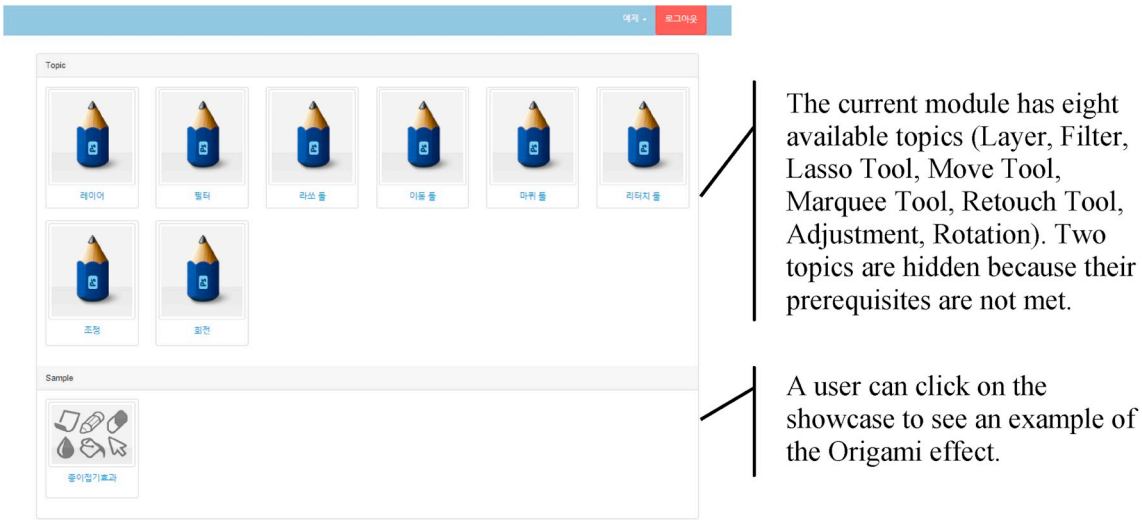


Fig. 3. A navigation screen for choosing topics.

Lepper, 1996; Parker & Lepper, 1992).

In digital games, fantasy is typically implemented by immersing players' in-game characters, stories, and worlds. Avatars, imaginary virtual worlds, adventure stories are used to facilitate such fantasies. Such objects and mechanics can be applied in a gamified e-training system. One strategy is to use fantasy avatars to denote achievements, as in the Jedi academy example. Though such fantasies may not provide cognitive benefits directly, they can create powerful emotional satisfaction that propels learners to be more engaged.

From the above discussion, we identify challenge, curiosity, and fantasy as the most relevant motivational drivers for e-training, and some game elements to create them. We next describe how we implement these motivational drivers.

4. Development of GAMESIT

4.1. Training content

We chose Adobe Photoshop as the training topic for two reasons. First, Adobe Photoshop is a very popular visual design software for professional designers and the creative community in South Korea, where our system was developed and tested. Second, Adobe Photoshop has an adequate level of complexity, making it a suitable topic for IT training research, and for the learning of conceptual and procedural knowledge (Santhanam et al., 2008; Yi & Davis, 2003).

Through this training, users are expected to understand various concepts and tools in Adobe Photoshop, e.g. layers, filters, feather tool, lasso tool, retouch tool, marquee tool, and paint bucket tool. They also learn how to perform various image-editing operations such as sketch effect, out-of-focus effect, edge effect, edge shadow effect, and origami effect. We explain these concepts and demonstrate these operations using text, images, and animations. In addition, we develop multiple-choice quiz questions related to the training content for assessment purposes.

4.2. The non-gamified E-training system

Similar to today's e-training applications, we implemented a “non-gamified e-training system” as a browser-based application, developed using open-source technologies including PHP, HTML, AJAX, and MySQL. The learning content in the e-training system was organized into modules, topics, and pages.

A user starts by choosing a *module* on a navigation screen. Each module consists of several *topics* (Fig. 3).[6,7] After choosing a topic, the user will go through a series of *pages*. These pages can contain declarative content (e.g., the introduction of a tool or concept) or procedural content (e.g., how to apply a particular technique on an image) (Fig. 4). Upon finishing a page, the user is presented a quiz question (See Appendix 4 for a sample question). After answering the question, a simple pop up window informs the user in the plain text whether the user answers the question correctly and the score for the current topic, then the user can proceed to the next page. A user completes a topic after going through all the pages in the topic. The training program has 6 modules, each of which has 3 to 8 topics. There are 5–8 quiz questions for each topic.

[6] For authenticity, we kept the original screenshots in Korean and add English annotations for understanding.

[7] Some topics have prerequisites. We will show them only when such prerequisites are met.

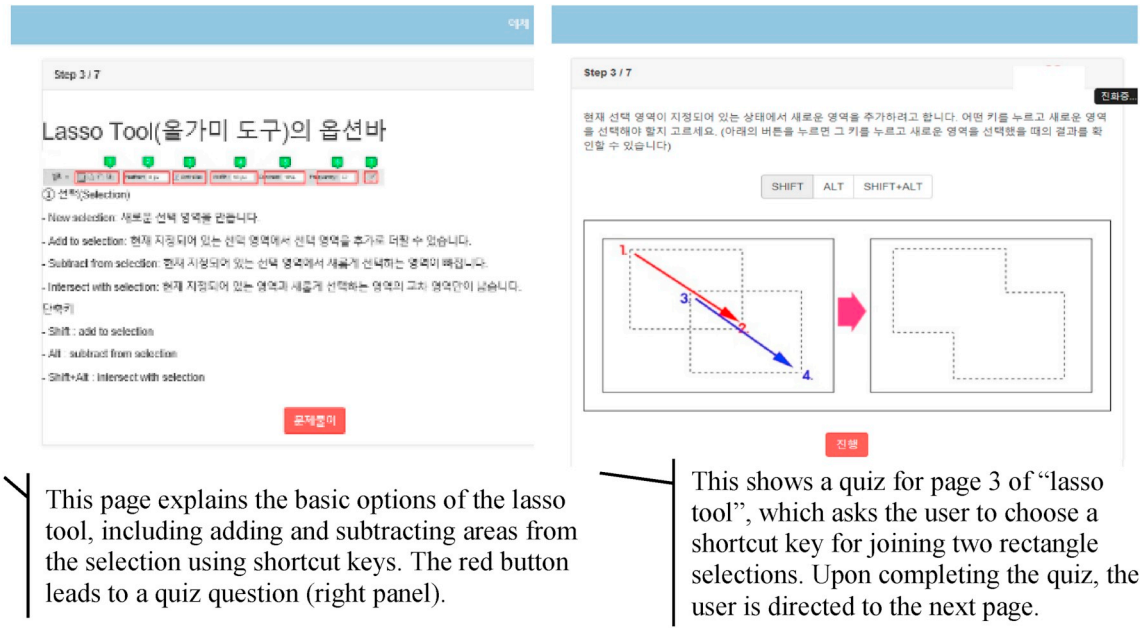


Fig. 4. A Sample e-training Page and the Associated Quiz.

4.3. The gamification layer

The purpose of the gamification layer is to enhance engagement with the e-training system while improving learning outcomes. Hence, we selected a set of gamification design elements that integrate well with the existing e-training system, and best serve as motivational drivers. For system-wide gamification design features, we introduced *experience points* and *levels*. A user can get experience points for answering a quiz question correctly and progress to a higher level after receiving enough experience points. There are 6 levels, which are visually represented by a series of avatars from an unhatched egg (level 1) to a fully-grown rooster (level 6) (Fig. 5). The experience points required for advancing to the next level increases with the level so that users can quickly advance to the second or third level but further advancements are increasingly more difficult. Level advancements are notified with a celebratory splash screen (Fig. 5).

We also implemented a "life" system. A new user starts each topic with a fixed number of "lives", which is set to one initially but increases by one for every two levels of advancement. When a user answers a question incorrectly, he/she loses a life. When a user has no life left, the user must restart the current topic with the number of lives restored to the starting level. We next discuss how gamification design features are used to generate the three motivational drivers. We note that each gamification design feature can create more than one motivational driver, and conversely, a motivational driver may be afforded by more than one gamification design feature.

4.3.1. Gamification design features that create challenges

Because the non-gamified e-learning system already has quiz questions that can serve as challenges, the goal here is to tune these challenges to make them more motivating. First, to make the existing challenges more salient, we borrowed from popular game designs by tying quiz performance to experience points, levels, and "lives". Success in a quiz results in more experiment points, level advancement, and even a bonus "life". Conversely, failing a quiz will result in the loss of experience points and even life. These provide a hierarchy of challenges (in the order of gaining experiment points, level advancement, and bonus life) so that learners can develop both proximal and distal goals.

Prior research indicates that to maximize engagement, the challenge should yield uncertain outcomes and match users' skill levels (Jagust et al., 2018; Malone, 1981). Hence, we arranged the questions such that the difficulty levels increase as users gain a deeper understanding of each topic. We designed the last question of a topic to be the "boss" question. Moreover, the level advancement is easy initially but becomes increasingly challenging as a user's level advances. These designs provide a variety of different challenges and keep the outcomes uncertain.

Another common strategy of increasing uncertainty is to use time constraints. Through the "life" system, we limited the number of wrong answers a user can provide for each topic. As mentioned before, a user has a limited number of "lives" and each wrong answer costs them a life. Such a gamification mechanic makes the outcomes more uncertain and prevents a user from attempting materials that are far above their current skill.

Per motivational theories, an important component of the challenge is immediate and clear feedback. We provide enhanced performance feedback immediately after a user answers a quiz question (Fig. 6). In addition, we use a dashboard to provide real-time

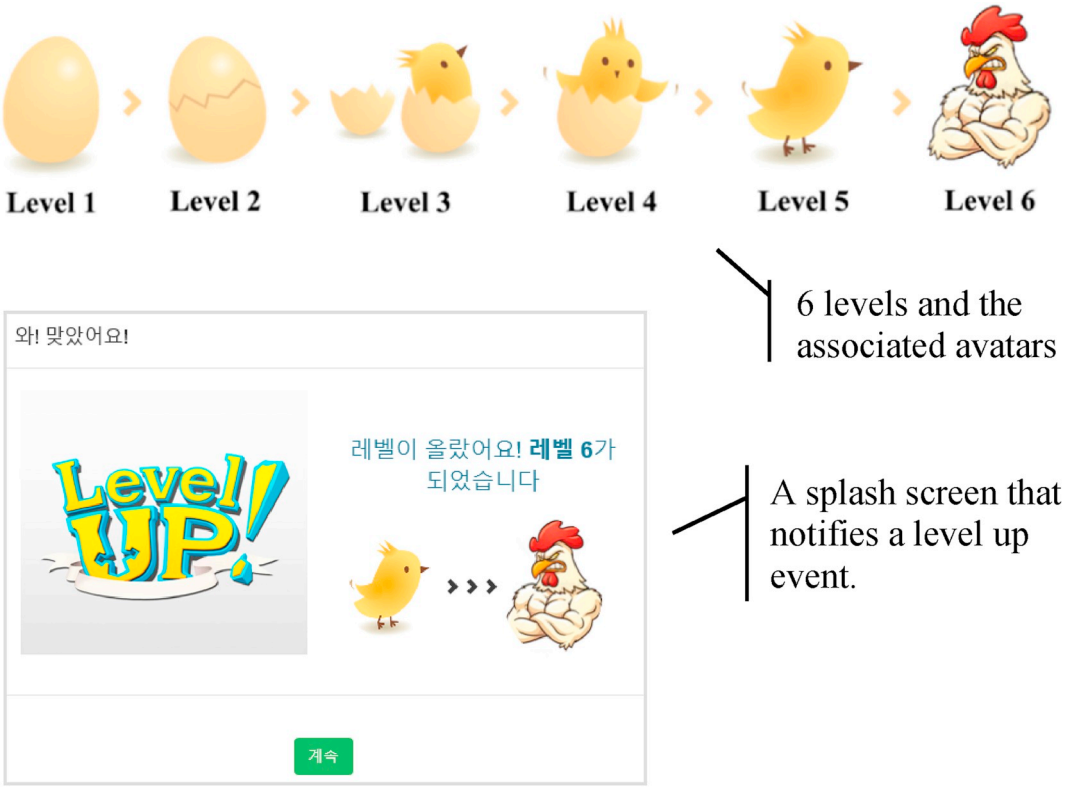


Fig. 5. Levels and a level-up screen.

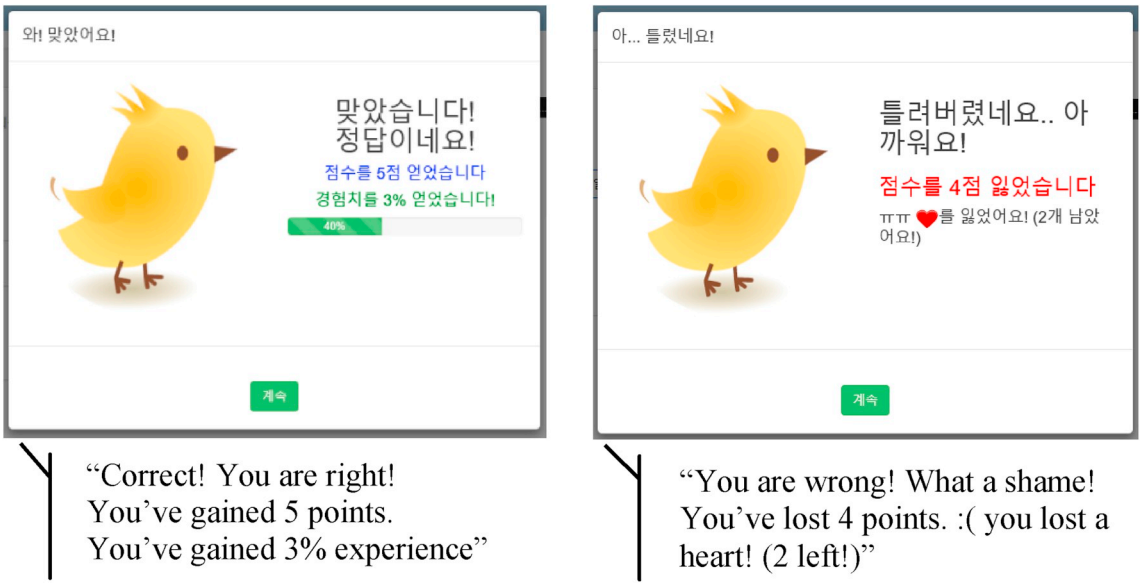


Fig. 6. Feedback for correct and wrong answers.

feedback on a user's performance in terms of experience points and level (Fig. 7).

4.3.2. Gamification design features that create curiosity

Several gamification objects and mechanics were aimed at creating curiosity. First, for each learning module, there is a showcase image illustrating Photoshop techniques introduced in the module. The showcase is initially locked, and a user can unlock it only after completing the module. This incompleteness of knowledge can evoke the curiosity of users and motivate them to complete the

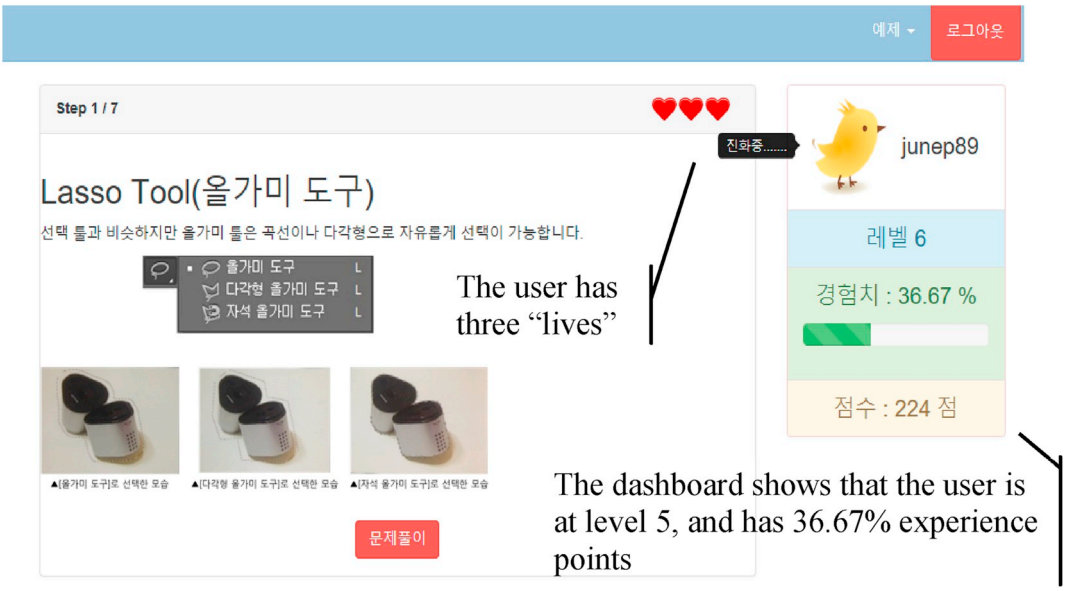


Fig. 7. A dashboard showing a user's current level and experience points.

module. Avatar evolution is another design feature whereby, as a user gains levels, the user's avatar also evolves, from unhatched egg to a fully-grown rooster. Because we do not divulge the forms of the avatar beforehand, it will create curiosity in users to find out what their avatar will be after they level up. We expect these design elements to create curiosity and motivate users to advance to a higher level.

4.3.3. Gamification design features that create fantasy

Avatar evolution can also serve as a driver of fantasy because its evolution accompanies a user's progression in the training. In the beginning, the avatar takes a primitive form of an egg. Gradually, it evolves into an egg with a crack, a half-hatched egg, and eventually into a mighty rooster. Through the illustration of the avatar's journey, as well as the exciting level up screen (Fig. 6), the user could form an attachment with the avatar, fantasizing about being the avatar, and experiencing the satisfaction of its growth. Another gamification object is the use of the heart as a symbol of "life," which accentuates the fantasy of gaining and losing a virtual life.

In Table 2 we map the key gamification design elements to create the three motivational drivers – challenge, curiosity, and fantasy, and as mentioned earlier, a gamification design element can serve as multiple motivational drivers.

4.3.4. Iterative development of GAMESIT

We developed GAMESIT through an agile development process with several iterations of user feedbacks and improvements (Gregor & Hevner, 2013; Hevner et al., 2004). Specifically, we first designed architecture of the system, and then developed a working prototype for iterative evaluation and improvements (Nunamaker, Chen, & Purdin, 1990). The iterative testing proceeded in two phases: a first phase consisted of informal focus group studies with the goal of improving the system's aesthetics and functions, and a second phase consisted of formal usability testing through protocol analysis, with the goal of validating the gamification design choices. The specific procedures were as follows:

In the first phase, we recruited four student volunteers as a focus group to interact with GAMESIT and provide feedback on the system's aesthetics and functionality (e.g. hyperlink arrangements and system responsiveness). The same volunteers interacted with

Table 2
Mapping motivational drivers to gamification design elements.

Motivational Drivers	Gamification Design Elements
Challenge	• A hierarchy of goals expressed in experience points, levels, and "lives." • A *"boss" question* at the end of each topic to make the outcome uncertain. • *Progressively more* challenging *levels.* • *Limiting the number* of *mistakes* one can make • *Instantaneous feedback* on quiz performance and a real-time *dashboard*
Curiosity	• *Avatar evolution* to make users curious about what's next • *Content unlocking* to encourage module completion
Fantasy	• *Distinct visuals* for performance feedback and avatar evolution to immerse users on a "journey" of their avatars • *Visual representation* of "lives" as hearts

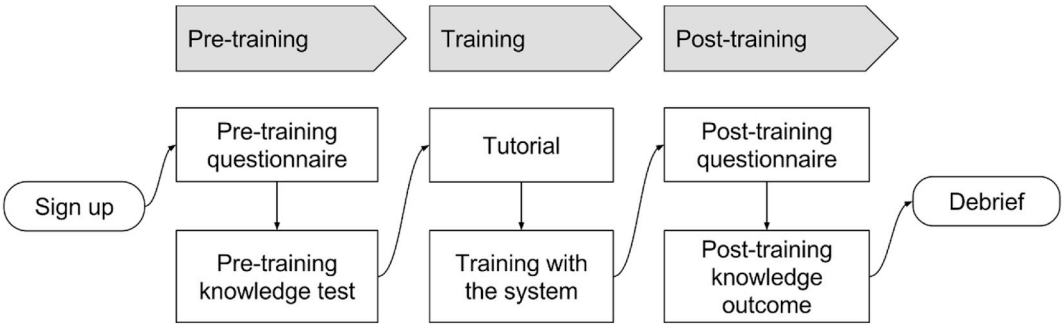


Fig. 8. Experiment flow chart.

GAMESIT and provided feedback three times with 1–2 weeks in-between for system improvements. In the end, the volunteers perceived the system to be easy-to-use and gave a positive appraisal of the system.

In the second phase, we recruited 6 student volunteers for systematic, in-depth protocol analysis with a focus on systematic usability (Benbunan-Fich, 2001; Mao & Benbasat, 2000). We first asked these volunteers to interact with the system and verbalize their thoughts and reactions following a think-out-loud approach. We then asked them a series of questions in a qualitative interview. We analyzed these protocols to identify and categorize user statements pertinent to the three motivational drivers, namely challenge, curiosity, and fantasy (sample coding is shown in Appendix 1). Based on the result of this protocol analysis, we concluded that our design adequately provided for these three motivational drivers. We then proceeded to conduct a systematic empirical evaluation of GAMESIT.

During the first two phases, we made several improvements based on feedback from users. For example, users noted that the size of the performance feedback window was small and located at the side of the screen, making them seem unimportant. In response, we made gamified feedback more animated and visually distinct and showed a larger window at the center of the screen. Users also found it difficult to achieve high levels in our early design. In response, we reduced the number of experience points required to advance to a high level, which made GAMESIT less challenging at low levels and more engaging.

5. Empirical evaluation of GAMESIT

We designed a laboratory experiment to evaluate GAMESIT against a "control" system, i.e., the e-training system without the gamification design elements, discussed in the previous section. Participants from both groups were presented with exactly the same training content, with the only difference being whether the gamification design elements were present or not (see Fig. 9).

Participants were recruited through an official online forum for students at a large research university, randomly assigned to either GAMESIT or the control system, and guided through the same three stages: pre-training, training, and post-training (Fig. 8). At the pre-training stage, we obtained their demographics, educational background, personality traits, and experiences with Adobe Photoshop using a questionnaire (Appendix 2). We then allotted participants 15 min for them to complete a 15-question pre-training knowledge test on Adobe Photoshop (Appendix 3). We did not give any feedback on their pre-training knowledge test. Next, an instructor conducted a 15-min tutorial session where participants interacted with the e-training system using the designated tutorial content. Following the tutorial, during the training stage, we let participants in the two groups freely interact with their respective target system for an hour and a half to complete the training. Finally, after the training, participants completed a questionnaire on their experiences with the system (Appendix 5). Following the questionnaire, they were given 15 min to complete another knowledge test, using the same questions from the pre-training knowledge test.

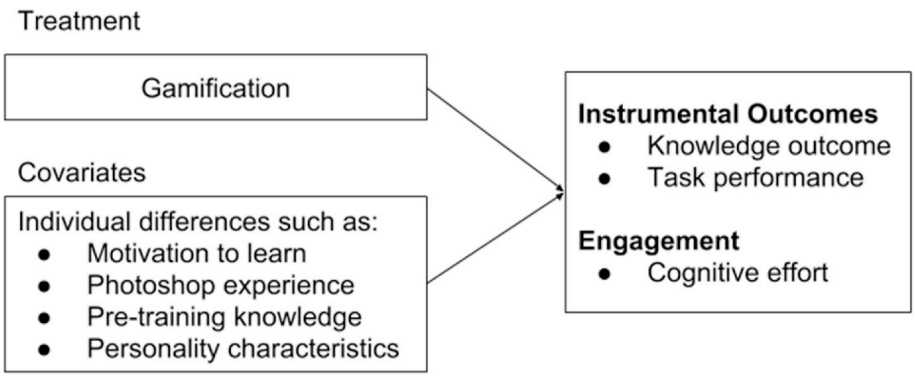


Fig. 9. Conceptual model for evaluation.

5.1. Participants

Eighty-one university students volunteered to participate in the experiment consisting of eight doctoral students, 10 master students, and 63 undergraduate students, from a variety of majors, such as biochemistry, electrical engineering, physics, life sciences, etc. The ages of the participants ranged from 17 to 30 with a mean of 21. Participants received a $10 gift certificate for their participation.

5.2. Variables

5.2.1. Dependent variables

The overall effect of gamification was measured using several dependent variables obtained from prior IT training research (Santhanam et al., 2008; Santhanam, Liu, & Shen, 2016; Yi & Davis, 2003). First, for learning outcomes, we measured knowledge comprehension and task performance. Knowledge comprehension was measured by the post-training knowledge test, which evaluated declarative and procedural knowledge (Appendix 3). Task performance was measured by the ratio of quizzes answered correctly by participants during the training (Appendix 4).

As discussed previously, we used cognitive effort as a measurement of engagement. The cognitive engagement was captured using the widely-used perceptual scale adapted from Kanfer and Ackerman (1989). Additionally, a participant's level of engagement could be indicated by how hard the participant is trying; therefore, we obtained “objective effort”, defined as the number of quiz questions attempted, as a supplemental measure of engagement.

We measured other variables used in training and gamification research, including self-efficacy and playfulness. In the training literature, a desirable outcome is for trainees to develop self-efficacy beliefs toward using this acquired skill (Compeau et al., 2006; Gupta, Bostrom, & Huber, 2010; Yi & Davis, 2003). Computer playfulness describes an individual's tendency to interact spontaneously and imaginatively with technology (Webster & Martocchio, 1992). In gamified training environments, achieving a state of playfulness could be an important outcome and was measured as in prior training studies (Webster & Martocchio, 1993).

5.2.2. Covariates

Prior research indicates that individual differences such as motivation to learn and personality characteristics could also explain training outcomes (Buckley & Doyle, 2017; Santhanam et al., 2013). Hence, we obtained participant demographics such as age, gender, academic status, and prior experience with Photoshop, as well as validated scales of individual traits including motivation to learn (Yi & Davis, 2003) and personality characteristics (Buckley & Doyle, 2017). *Motivation to learn*, defined as the user's motivation to learn the content, is identified in prior research as a predictor of training effectiveness and user engagement, and is typically measured in training research (Gupta et al., 2010; Yi & Davis, 2003).

Personality characteristics as individual differences are noted as influencing user experiences and learning outcomes during training (Buckley & Doyle, 2017; Santhanam et al., 2013). Hence, we identified several personality characteristics including *neuroticism*, *openness*, *extraversion*, and *agreeableness* as controls that were used in prior studies when users faced new and uncertain contexts, such as one would find in a new gamified training environment (Broadbent, 1958; Buckley & Doyle, 2017; Furneaux, 1961; Graziano & Eisenberg, 1997).

Table 3
Descriptive statistics.

Variables	Range	Mean (S.D.)			t- statistic (significance)
		All N = 81	Control N = 41	GAMESIT N = 40	
Percentage of males		65.4%	63.4%	67.5%	
Age	17–30	21.20 (3.01)	21.68 (3.13)	20.70 (2.82)	1.48 (0.14)
Academic Status					
- Undergraduate		63	28	35	
- Masters		10	8	2	
- Doctoral		8	5	3	
Photoshop Experience					
- Experienced		46	20	26	
- Not Experienced		34	20	14	
- No Response		1	1	0	
Pre-training Knowledge	0–15	6.70 (3.59)	6.37 (3.35)	7.05 (3.84)	−0.86 (0.40)
Motivation to Learn	1–7	5.59 (0.99)	5.76 (1.01)	5.42 (0.95)	1.59 (0.12)
Neuroticism	1–7	3.59 (1.11)	3.65 (1.14)	3.53 (1.08)	0.47 (0.64)
Openness	1–7	4.56 (0.87)	4.37 (0.83)	4.74 (0.89)	−1.93 (0.06)
Extraversion	1–7	4.55 (0.99)	4.67 (0.81)	4.43 (1.14)	1.08 (0.28)
Agreeableness	1–7	4.76 (0.90)	4.76 (0.84)	4.75 (0.97)	0.01 (0.99)

Table 4
Cronbach's alpha, composite reliability, and average variance extracted.

Constructs		Cronbach's Alpha	Composite Reliability	AVE	Construct Correlation		
					1	2	3
1	Self-efficacy	0.96	0.96	0.78	**0.88**		
2	Cognitive Effort	0.87	0.91	0.76	−0.19	**0.87**	
3	Playfulness	0.85	0.91	0.76	−0.31	0.13	**0.87**

6. Findings

We first present descriptive statistics on the study variables as shown in Table 3, which indicates no significant differences in the demographic make-up of the two groups – GAMESIT and control. No significant differences are observed in gender, age, academic status, Photoshop experience, or pre-training knowledge across the two groups. The gamified group had more undergraduate participants, and a higher proportion of participants with Photoshop experience, but these were not significantly different.

We conducted correlational analysis between individual difference variables and dependent variables, and to improve the precision of the estimated treatment effects, we included neuroticism, extraversion, motivation to learn, prior experience on Photoshop, and pre-training knowledge as covariates in our final analysis, because they correlated with dependent variables.

6.1. Reliability and validity

Before conducting the analysis, the psychometric properties of the measurement scales were tested. The internal consistency of scales is commonly assessed using the composite reliability and Cronbach's Alpha, and a measure is generally considered adequate when over 0.7 and excellent when over 0.9. The convergent and discriminant validity of the measurement items are commonly assessed by comparing a construct's square root of Average Variance Extracted (AVE) and that construct's correlation with other constructs. The overall reliability and validity of the constructs are summarized in Table 4. The square root of AVE of each construct, shown in bold, is larger than its correlation with other constructs and satisfies convergent and discriminant validity. Cronbach Alpha scores of over 0.7 show that tests of reliability are also satisfied.

6.2. Analysis of the effect of gamification

An Analysis of Covariance (ANCOVA) analysis was conducted to evaluate the effect of gamification, controlling for the effect of several covariates. The results of this are shown in Table 5. To give an idea of the effect sizes, Table 5 also shows the marginal estimated means for the treatment and control groups, adjusted for the effects of covariates.

We observe a statistically significant difference in our dependent variables of comprehension ($F = 4.06$, $p = 0.05$), task performance ($F = 6.06$, $p = 0.01$), cognitive effort ($F = 7.40$, $p = 0.01$) and objective effort ($F = 46.72$, $p < 0.001$) between participants who used GAMESIT and those who used the non-gamified e-training system. The analysis of marginal estimated means further showed that GAMESIT resulted in improved comprehension and task performance, as well as engagement in terms of cognitive and objective effort.

We observe a significant difference for playfulness ($F = 3.18$, $p = 0.08$), but did not observe a significant difference for self-efficacy between the two groups ($F = 0.52$, $p = 0.47$).

Table 5
ANCOVA results.

	Learning Outcomes		Engagement		Other Outcomes	
Dependent Variable	Comprehension	Task Performance	Cognitive Effort	Objective Effort	Playfulness	Self-efficacy
Treatment Effect:	4.06 (0.05)	6.058 (0.01)	7.22 (0.01)	46.72 (0.00)	3.18 (0.08)	0.52 (0.47)
F (p-value)	*	**	**	***	+	
Covariates: F (p-value)						
Neuroticism	0.02 (0.89)	0.13 (0.72)	10.31 (0.00)	2.49 (0.12)	0.42 (0.52)	5.48 (0.02)
Extraversion	3.19 (0.08)	0.18 (0.67)	1.87 (0.18)	6.36 (0.01)	1.00 (0.32)	0.30 (0.59)
Motivation to Learn	0.00 (0.97)	1.26 (0.27)	6.95 (0.01)	0.00 (0.95)	3.29 (0.07)	1.33 (0.25)
Photoshop Experience	0.05 (0.83)	0.25 (0.62)	0.87 (0.36)	1.64 (0.20)	2.82 (0.10)	0.43 (0.51)
Pre-training Knowledge	4.21 (0.04)	3.91 (0.52)	0.02 (0.90)	0.31 (0.58)	2.55 (0.12)	9.79 (0.00)
Adjusted R^2	0.10	0.10	0.232	0.39	0.11	0.21
Marginal Estimated Means (S. D.)						
Overall	12.45 (0.22)	0.79 (0.01)	3.48 (1.63)	85.19 (1.41)	3.56 (0.12)	6.10 (0.08)
Control	11.97 (0.33)	0.78 (0.01)	3.24 (1.52)	74.92 (2.06)	3.33 (0.18)	6.03 (0.12)
Treatment	12.93 (0.32)	0.81 (0.01)	3.73 (1.71)	95.45 (0.21)	3.79 (0.18)	6.16 (0.12)
Range	1–16	0–1	1–7		1–7	1–7

***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$, +: $p < 0.10$.

We noted, however, the outcomes on self-efficacy were high for both the GAMESIT and control groups. One explanation is that if participants already had high self-efficacy beliefs before the training, a gamified training session may not increase it significantly. Indeed, a post-hoc analysis showed that for participants who had low pre-training knowledge test scores (a proxy for low self-efficacy), the use of GAMESIT resulted in improved self-efficacy scores, but for those who reported relatively high pre-training knowledge, it did not.

7. Discussion

Gamification is seen as a promising approach to improve learning and engagement outcomes in e-training, yet there are conflicting findings and questions on design and efficacy. To address these questions, we designed GAMESIT using guidance from the theory of intrinsically motivating instruction. Our evaluation of GAMESIT, a gamified e-training system, vis-à-vis the non-gamified e-training system indicates that our theory-driven and systematic gamification design was indeed effective in improving learning and creating engagement.

7.1. Implications

Our study firstly has implications for gamified learning research by offering evidence that a theory-driven design science approach to gamification, despite being done by academics with little game-design experience and a very limited budget, can deliver good results. We moved away from existing gamification solutions that rely on points, badges, and leaderboards and focused instead on providing the motivational drivers for learning tasks suggested by theory: namely, fantasy, challenge, and curiosity. We incorporated common game elements such as experience points, levels, and avatars, but we also paid much attention on designing the user experiences that went with these elements (e.g. the fantasy of avatar evolution, challenge gradation, and content unlocking) and on aligning game advancements with learning progresses (e.g., we require a user to restart a topic after he lost all of his “lives”). We show that our gamification design, despite lacking fancy features such as 3D animations, simultaneously improved learning and engagement. Our positive results contrasted with the more pessimistic findings in the gamified e-learning literature and highlighted the value of incorporating affordances beyond points/badges/leaderboards and employing a theory-based design process for gamification, which are called for by several authors (Hamari et al., 2014; Rapp et al., 2019). Taken together, our study echoes the sentiment that a lack of thoughtful designs may have contributed to some of the noted failures in gamified learning systems.

Our study on GAMESIT also advances the e-training research. The landscape of e-training has shifted dramatically in recent years from instructor-led classroom training to feature-rich platform-based e-training for self-paced learners. This shift requires both new theoretical perspectives (e.g. those addressing engagement) and guidelines on how to translate these theoretical perspectives into effective designs. As demonstrated in this study, it was useful to bring in theoretical perspectives on motivational drivers such as challenge, curiosity, and fantasy, and translate those into gamification design features layered on top of an e-training system. So far much of the gamified e-training research uses the self-determination theory as a high-level theoretical framework (Ding et al., 2017; Rapp et al., 2019; van Roy & Zaman, 2018). To the best of our knowledge, we are the first to use Malone's theory of intrinsically motivating instruction in designing gamified e-training. We believe such lower-level theories may have some advantages in guiding designs.

Finally, this research illustrates a process by which one can systematically develop and test theory-driven gamification designs, including how to choose gamification design features to provide motivational drivers suggested by theory, and how to test the overall effectiveness of such design through a randomized experiment. In this process, we took several measures to mitigate some of the known risks of gamification. For example, to prevent voiding of user experiences and “pointification,” we did not use badges or leaderboards. We used points and levels but coupled them with the fantasy of avatar evolution so that users can become invested in the progression of the avatar and less focused on gaining “points.” Our use of challenge gradation, “boss” questions, and a life system also created suspense and enriched user experiences.

In our iterative design and development, we have learned a few design lessons that could be helpful in future gamification designs. First, the added game elements and gameful feedback should be vivid and visually salient. Otherwise, they may not be strong enough to convey a sense of a gameful environment and as a result, users may not engage. Second, due to the complex environment, users can easily overlook the gamification elements unless there are explicit directions and the instructions are easy to follow. Third, challenge levels have to be implemented in a way that users do not feel discouraged and they are always provided alternative pathways.

7.2. Limitations and future research

This study has several limitations. First, we used a single training content, namely Adobe Photoshop. Research on other IT training tasks is needed before one can draw general conclusions. Second, we used only student participants for evaluation, which may limit its generalization to a broader set of organizational learners. We note though, that e-training systems are also used in educational institutions. Third, our positive results were based on the short-term use of GAMESIT and thus could have benefited from the “novelty effect.” (Seaborn & Fels, 2015) We argue, though, that most of our subjects were familiar with the gamification elements that we introduced (e.g., points, levels, and avatar) and it was unlikely that our results were driven entirely by novelty. Fourth, we used a self-reported measure of cognitive engagement, which may be limited by the subjects' ability to introspect and rate their effort expenditure correctly. A multi-method measurement of engagement and newer techniques of brain imaging such as

electroencephalography (EEG) can complement and enhance the measurements used in this study. Fifth, our gamification design focused on non-social game elements that were most relevant to Malone's theory. Future research could evaluate social game elements such as competition and gift exchanges (Krause, Mogalle, Pohl, & Williams, 2015; Rapp, 2017). Sixth, a closer examination of individual differences and personalization will likely increase the power of a technology platform for training (Ayoung, Wagner, & Liu, 2015; Buckley & Doyle, 2017).

In conclusion, although a number of gamified learning systems have been developed, their impact on learning has not all been positive. Researchers have called for theory-based designs and more rigorous empirical evaluation to advance the design and evaluation of gamified learning systems. We answered this through iterative design and development of GAMESIT – a learning system for technology training – using Malone's theory of intrinsically motivating instruction. We found that our theory-based design achieved the desired positive outcomes of gamification. We provide detailed descriptions of our approach so that it can serve as a guideline for the future development of gamified learning systems.

Appendix

Appendix 1. Sample Protocols Used in the Formal Usability Testing

Motivational Drivers	Sample Protocols
Challenge	• Is this supposed to be this difficult? I have to memorize things. • So, it seems I'll be doing things altogether. But I am not able to remember much. • Let me do this, this seems to be difficult • This cannot be for beginners
Curiosity	• Why is the egg cracked? Was it supposed to be cracked? What makes it cracked? • Oh, does this feature control the blur size? So you can smudge with it. Oh, this goes to the brightness. • Oh, So, is it supposed to work from the left? • It used to be two layers … why is it three now?
Fantasy	• The egg broke and the chick came out. Hm, maybe it ends when the chick comes out. • Oh, the chick changed. The chick changed? What? • Oh, wow, it's a muscular chicken, chick to a chicken, got it • So the egg seems like its cracking, so the chick comes out • The level is 5, 12% experience point, oh, so the experience points level me up and make the chick to turn into a chicken • Gaining experience points and being able to see it is pretty good • I got it right, so the egg cracked and a chick popped out

Appendix 2. Pre-Training Questionnaire

A. Selected Background Questions

If you have used photoshop before, how long have you used it for?
1) 1 year or less
2) More than 1 year and less than 3 years
3) more than 3 years and less than 5 years
4) more than 5 years and less than 7 years
5) more than 7 years

Please rate your knowledge of Photoshop
○ Low ○ Medium Low ○ Medium ○ Medium High ○ High

B. Sample Measures of Individual Differences

All measures are on a 1–7 scale anchored on “strongly agree” to “strongly disagree”. Factor loadings for individual items are in parenthesis.

Extraversion (Costa & McCrae, 1992) Cronbach α = 0.81
I am the life of the party. (0.76)
I start conversations (0.92)
I talk a lot (0.79)

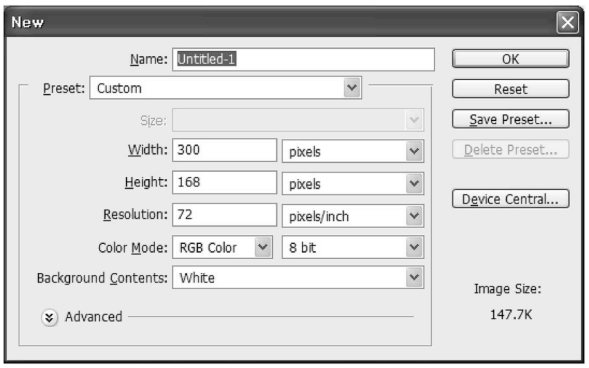
Neuroticism (Costa & McCrae, 1992) Cronbach α = 0.83
I worry about things (0.71)
I often feel blue (0.71)
I am easily disturbed (0.85)
I change my mood a lot (0.90)

Agreeableness (Costa & McCrae, 1992) Cronbach α = 0.82
I am interested in people (0.72)
I have a soft heart (0.81)
I make people feel at ease (0.83)
I feel others emotions (0.76)

I sympathize with others feelings (0.71)
Openness (Costa & McCrae, 1992) Cronbach α = 0.76
I have a rich vocabulary (0.75)
I have a vivid imagination (0.76)
I have excellent ideas (0.71)
I use difficult words (0.81)
Motivation to Learn (Davis, Khazanchi, Murphy, Zigurs, & Owens, 2009) Cronbach α = 0.86
I am very much interested in learning about photoshop in this training session (0.90)
I am excited about learning the photoshop skills that will be covered in this training session (0.90)
I will try to learn as much as I can from this training session (0.86)

Appendix 3. Sample questions from Photoshop knowledge test

1. In order to make a new image file, the new image option on the file menu has been pressed and showed the following image. What is the function that cannot be adjusted in this new image option?



A. Select the canvas size as film size
B. Select the canvas background color to be transparent
C. Adjust the canvas margin in mm scale
D. Select the canvas color mode in Gray Scale
E. Select the canvas resolution to be 30 pixels/cm

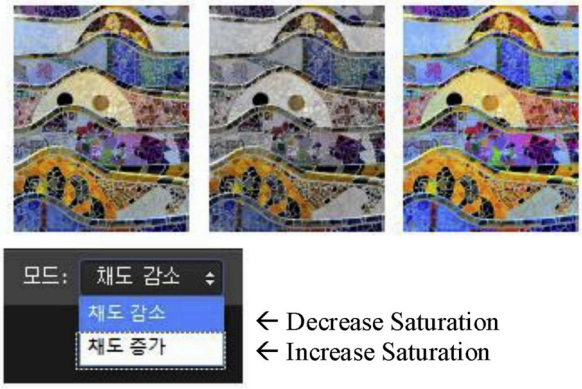
2. The following are the possible steps in making an edge shadow effect. Please choose the most appropriate order of the given steps. 1) Copy the image to a new layer. 2) open the image 3) close the background layer. 4) Select a specific area with the lasso tool.
A. 2-1-3-4
B. 2-4-3-1
C. 2-4-1-3
D. 2-1-4-3

3. What key must be pressed in order to copy and move a selected area in Adobe Photoshop?
A. ALT
B. CTRL
C. SHIFT
D. SPACE

4. What is the option to smoothen the contrasting line between colors or patterns?
A. Invert
B. Anti-aliasing
C. Opacity
D. Contrast

Appendix 4. Sample Quiz Question

Observe the three images below. Which option from the dropdown list shown below should you choose to convert the first image to the third image?



Appendix 5. Post-training Questionnaire

All measures are on a 1–7 scale anchored on "strongly agree" to "strongly disagree". Factor loadings for individual items are in parenthesis.

Cognitive Effort (Kanfer & Ackerman, 1989) Cronbach α = 0.87
I focused my total attention on learning as many basic concepts about Photoshop as possible. (0.81)
I focused my total attention on developing my skills in using Photoshop. (0.86)
Photoshop Self-efficacy (Marakas, Yi, & Johnson, 1998) Cronbach α = 0.96
I believe I have the ability to create new image files in Photoshop (0.86)
I believe I have the ability to create, copy, delete layers in Photoshop (0.95)
I believe I have the ability to use the lasso tool to manipulate sections in Photoshop (0.90)
I believe I have the ability to move selected items using the move tool in Photoshop (0.89)
I believe I have the ability to color specific regions using the paint bucket tool in Photoshop (0.93)
I believe I have the ability to make a photo black and white using adjustment tool in Photoshop (0.86)
I believe I have the ability to control the brightness and contrast using adjustment tool in Photoshop (0.84)
Playfulness (Webster & Martocchio, 1992) Cronbach α = 0.85
When I interact with this system, I am imaginative (0.83)
When I interact with this system, I am flexible (0.77)
When I interact with this system, I am creative (0.80)
When I interact with this system, I am inventive (0.85)

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