Impacts of Game-based Feedback and Peer Interaction Mechanisms on Learning Performance and System Use

Chun-Wang Wei[1,a,*], Li-Ling Chen[2,b] and Nian-Shing Chen[2,c]

[1]Department of Management Information System, Far East University, Taiwan

[2]Department of Information Management, National Sun Yat-sen University, Taiwan

[a]cwwey@cc.feu.edu.tw, [b]susanna2222@gmail.com, [c]nschen@mis.nsysu.edu.tw

*Corresponding author

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Abstract. There are still many subjects which are difficult to be developed as digital learning games. In order to provide the entertainment element for those kinds of subjects, this study attempted to propose two learning support mechanisms for learners. One is game-based feedback which provides useful information for learners to engage in further learning after the game stage. The other is peer interaction which constructs an environment to facilitate learners interacting among each other. An experiment was conducted with a total of 80 students enrolled in Computer Networks course. The results show that the mechanism of peer interaction has a significantly positive effect on learning performance, and the mechanism of game-based feedback has a significantly positive effect on the intention toward using the developed system for their further learning.

1. Introduction

Previous studies have shown that digital game-based learning helps learners develop self-efficacy, critical thinking skills and problem-solving abilities, as well as enhancing the interest of learning [7, 8, 13]. Digital learning games allow deployment of mission objectives, predetermined templates and rules to provide real-time feedback for enhancing learners' understanding of the learning objectives [10]. Most digital learning games are simulation-based, allowing learners to embed themselves into a pre-determined learning environment. Simulation-based games are ease of demonstrating learning results from the processes of problem resolution and solving challenges. Therefore, English conversation, historic classics, animal husbandry, plant cultivation, finance and investing, or other curricula requiring practicums, are particularly well-suited for simulations in digital learning games. However, not all curricula can be easily adapted to an interesting learning game, especially for courses requiring abstract principles. For example, calculus operations, IP address subnetting, or philosophical questions.

Currently, most digital learning games are based on combination of learning content and timely feedback in the game processes. Learners have to use their prior knowledge to deal with the game challenges, not merely playing the game for fun. However, learners may feel loss the joy of playing games when the learning task cannot be properly immersed in the game processes. Therefore, it is an important issue to ensure that playing games is joyful and benefits to learning performance. This study aims to develop an integrated strategy for permitting the learning process to be interesting and useful for deployment across the majority of curricula. The proposed strategy includes two main mechanisms of game-based feedback and peer interaction.

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Learner feedback intends to provide information which is relevant to the learning objectives and learner processes, so as to adjunctively support learners existing understanding in reaching their curricular demands [3, 6]. Constructive feedback may be helpful in permitting learners to maintain their interest in learning activities and for further study. Moreover this can help stimulate learners more efficacious learning and accelerate the learning curve to overcome obstacles to learning [1]. Therefore, learning feedback is imperative to progress in learning.

This study examines a constructive feedback mechanism imported to a digital learning game, referred to as "game-based feedback." A learning system was developed to transform the learning progress indicia to unique parameters in the digital game. As learners progress in their learning, characters, equipment and parts in the game will be progressively enhanced, and better able to overcome the game design's mission challenges. Of course, playing the game will become more fun. However, as learners are unable to resolve the game difficulties, the system will provide appropriate feedback based on evaluation results. This permits learners to enjoy some self-renewal before returning to face more challenges.

Most digital games provide individual player modes and multiplayer mode designs. In multiplayer modes, players can interact with others, enhancing their interest in the game. Social cognition theory emphasizes that mankind are active doers, while most learning comes through observation as affected by their appurtenant environmental impacts [2]. If one is to establish a productive interactive learning environment, this will help in advancing sharing of knowledge and experience. Peer interaction refers to interactivity among those of similar age, with a common social status and interests. Excellent peer interaction is helpful for developing knowledge and interpersonal relations [5]. To enhance game-based feedback results, this study imported a "peer interaction" mechanism into the system. This permits the digital game to act as a mediator, as the learners play the digital game together. As the digital game ends, the system analyses each participant's difference in understanding the learning objectives, and guides the learners to appropriate a discussion. This helps the learners better understand the curricular knowledge. On the other hand, there is the individual learning milieu. The peer interaction mechanism helps learners engage their personal learning status, and to interactively engage in learning with their cohorts, achieving the interactive objectives [4].

This study aims at establishing a digital learning environment which integrates "game-based feedback" and "peer interaction." Through the digital game facilitated learning feedback, cohort-mediated learning is also advanced. This then results in greater learning efficacy and greater application of the learning system. Therefore, the core research issues involve whether the game-based feedback mechanism and peer interaction mechanism can efficaciously enhance learners' learning performance? Additionally, this study explores whether learners using the game-based feedback mechanism and peer interaction mechanism, can deploy a positive attitude and intention?

2. Learning environment

This study deploys learning materials, progress evaluation questions and the digital game in an online platform. This permits learners to enjoy asynchronous learning and synchronous interactivity anytime. The learning system supports reading the learning material, progress evaluation questions, game-based feedback and peer interaction, so learners can rely on their current status at anytime to proceed with an appropriately leveled learning activity.

2.1 Reading learning materials

The system works with multimedia educational content to provide adjunctive learning support for learners. This study provides educational content in the form of digital e-books as shown in Fig. 1, including text, photos, and explanatory videos. Learners can click on page corners or lift up a page

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corner to flip the pages. At the top of the subsections there is a hyperlink tab, which instantly connects to the subsections' linked page.

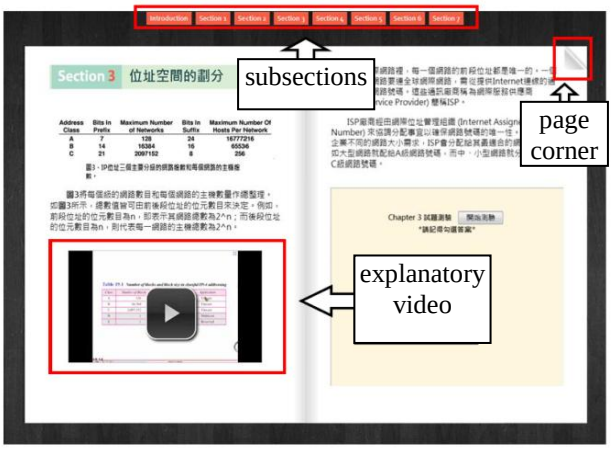

Fig. 1. E-book formatted digital learning contents.

2.2 Assessment evaluations

As learners complete a subsection of learning content, they face assessment evaluations. If they click on the assessment functions, they can obtain evaluate their learning results. This study used evaluation questions to conduct the learning assessments, with randomly assigned questions and multiple answer questions for each subsection. After completing the evaluation, the system will only display whether the answer is correct, but will not display the actual correct answer. This permits learners to achieve learning success by acquiring the learning objectives through their own independent initiative. Additionally, this facilitates transformation of learners' abilities to the digital game's functional parameters. Each evaluative item corresponds to a level of the cognitive process dimension. The cognitive process dimension includes the six aspects of memory, understanding, application, analysis, evaluation and innovation [9], while there is particular difficulty with evaluating creativity by using only multiple-choice questions. Thus, this study only explores the categories of the first through fifth aspects. Each learner is provided with a unique login account and password. The system transforms the assessment evaluation result scores to cognitive process dimension. These scores determine the digital game functions' control parameters.

2.3 Game-based feedback

The game-based feedback mechanism refers to means of permitting learners to understand their own learning status, and to facilitate ameliorative efforts for areas in need of learning reinforcement. This study focuses on exploring whether the entire learning process deployed is successful in aiding learning efficacy. Thus, a simple shooting game was used to reduce the learning curve for the game. The system will provide an overview of the cognitive process dimensions before entering the game, and detailed feedback will be provided after the game. These will include the results at all levels of the cognitive process dimensions, and the degree of familiarity with each of the subsections. Then learners can apply the feedback results, to enhance their learning performance.

The game of this study deploys requires 30 seconds, and learners can use the left and right motion keys to move a spaceship and the space bar to launch missiles. Striking a target monster accumulates points, while being successfully attacked by a monster causes one to lose points. The game includes display of the spaceship speed and the number of enemies successfully attacked. The system can capture and calculate the learner's cognitive process dimension scores. This study uses basic skills to control the spaceship speed. Advanced skills are used to determine scores for successfully attacking enemies. Basic skills are composed of the combined scores for memory and understanding levels,

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while the advanced skills are composed of apply, analysis and evaluate level scores. Spaceship speeds consist of either fast, moderate or slow. So for exceptional learners, spaceship speed will be faster, and the scores for attacking enemies shall be 10, 5 or 3 points. Thus, advanced skills attacks on enemies will generate higher scores.

When only a single player is playing, and there is no cohort opponent for comparison, the learner will only see their game results and learning feedback. If there are two players, the system will perform comparisons of the two learners' capabilities. Then the system will display feedback about each learner, to help foster their peer interaction.

2.4 Peer interaction

This study establishes a peer interaction mechanism amidst the game process, using the digital game as a medium for interactivity. As the game ends, the system will display the two learners respective capabilities and scores. Learners can then use the game results, to engage in a discussion of the learning material contents or evaluative question items. Besides facilitating learners appreciation of the areas in which they may need to enhance their learning, they can also compare their learning results with their cohort learning partners. So the system provides definitions of skills, explanations and sample items, to help learners guide their cohorts to obtain better understanding.

3. Research methods

This study relies on an empirical study method to explore "game-based feedback" and "peer interaction" mechanisms' impacts on learner efficacy and willingness to engage in system use. The experimental learning content subsections include seven IP areas: internet protocol addresses in Computer Networks, exploring the methods of forming IP addresses, including IP addresses, IP address classification, address space division, subdomains and address masks, CIDR notations, special IP addresses, and Examples of using Subnet Masks. In addition to basic IP addressing methods, there is also content such as advanced IP cutting and subnet masking which also require calculations. The learning content is categorized into types and then processed into a-book formats for use in the study. In order to correctly evaluate learning efficacy, subject matter experts designed the pre-test and post-test sample items. Each of these tests consisted of twenty multiple-choice items, covering cognitive process dimensions of memory, understand, apply, analysis and evaluate.

Thus this experiment requires a basic understanding of internet principles and binary computing. Therefore, the study selected information science students from a single university to participate as study subjects, and a total of 80 students volunteered to participate in this study. It was also necessary to empirically examine the results of the game-based feedback and peer interaction mechanisms. So the study designed four groups consisting of a control group, game-based feedback group, peer interaction group, and game-based feedback and peer interaction group. Then the study participants were randomly assigned to groups, with 20 subjects in each group.

Before the experiment an explanation was provided to the participants about their assignments to various groups and the experimental processes. Then the pre-test was conducted for fifteen minutes, to gain an appreciation for the participant's level of understanding of the test subjects. In the actual test, each group would first have 40 minutes to read the learning materials and undertake the evaluative assessment. Then the different groups would have various 30 minute learning activities. After the learning activities were completed, they would have ten minutes to complete the Questionnaire, and then 15 minutes for the post-test.

So the entire test time per group was 70 minutes. This involved two periods, one consisting of the learners having 40 minutes to independently read the learning materials and complete the evaluative assessment, in a process which was the same for all groups. Then a second phase of thirty minutes differed for each group. The process for this phase was as follows:

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3.1 Control group

This group does not have either game-based feedback or the peer interaction mechanism, but relies on traditional digital learning methods, and is used to establish a baseline with the other three groups. The second phase consists of the learners engaging in their own practice.

3.2 Game-based feedback group

This group consists only of the game-based feedback mechanism, and does not have the peer interaction mechanism. The second phase is used for playing the group to receive learner feedback, and then to engage in follow-up practice learning activities.

3.3 Peer interaction group

This group only has the peer interaction mechanism, and does not have the game-based feedback mechanism. Since this requires peer interaction, the twenty participants assigned to this group were further randomly assigned into ten teams with 2 peers in each team. The second phase permitted participant peers in each team to engage in independent discussion and interactivity about the learning material content and subjects. Since there was no game-based feedback mechanism, the system did not display the learners various relative cognitive process dimension capabilities.

3.4 Game-based feedback and peer interaction group

This group enjoyed both the complete game-based feedback and peer interaction mechanisms. The group's twenty subjects were randomly assigned into ten teams. The second phase consisted of permitting the team peers to engage in the game-based feedback and peer interaction. When the game was over, the system displayed the team peers two scores and cognitive process dimension distributions. Additionally explanations of the capabilities, learning hints and sample questions, helped guide learners to understand what each dimension meant and engage in interactive learning.

4. Results

Among the 80 study subjects, there were 45 males and 35 females. Forty-two were undergraduates and thirty-eight were Master's degree candidates. The study used one-way ANOVA, to examine the pre-test to determine the four groups understanding of the study learning materials. The results indicated no significance (p=.674) for the pre-test, and hence the participants were randomly assigned to the groups as desired.

Then we analyzed post-test data, using two-way ANOVA to explore the game-based feedback and peer interaction mechanisms' impacts on learner efficacy. The results indicated that interactions among game-based feedback and peer interaction were not significant. Then the two mechanisms post-test scores primary results indicated that the game-based feedback mechanism did not exercise significant effects on post-test scores. However, the peer interaction mechanism exercised a positive significant effect on learner efficacy. Therefore, we explored the peer interaction mechanism on post-test scores through an independent samples T-test. The results indicated that in the groups with peer teams, learner efficacy was significantly higher than for groups lacking peer interaction.

This study applied the technology acceptance dimension's use attitude and use intention aspects to enquire of participants' attitudes and intentions for using this learning mechanism. Then we used the two-factor analysis of variance test to explore the game-based feedback and peer interaction mechanism affecting on attitude and intention to use this learning mechanism. The results indicated no interaction among the two mechanisms, and the peer interaction mechanism did not have significance on use attitude or use intention for this learning mechanism. However, the game-based feedback mechanism did have a significant impact in use attitude and use intention. Therefore, we explored whether the game-based feedback mechanism affected use attitude and use intention

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through an independent samples T-test, and the results indicated that for the groups with the game-based feedback mechanism, their use attitude and use intention were significantly higher than for the groups without the game-based feedback mechanism.

From the statistical analysis we can see, the learning mechanism which can effectively enhance learner efficacy is the peer interaction mechanism. But it is the game-based feedback mechanism which helps learners use attitude and intention to engage in this learning mechanism. Thus the two mechanisms interaction results are complementary.

5. Discussion and implications

Deploying the game-based feedback mechanism in a digital learning mechanism, exercised learning efficacy impacts in this study which were not significant. The study undertook interviews with participants in regard to this issue. We discovered that the study design for the game was too simple for the students and was not challenging enough. Thus the learners were unwilling to play the game, and at the same time this meant the game gave less feedback to display the learner's abilities. The study deployed five cognitive process dimensions to categorize the questions. Learners can score while completing the questions, and examine their learning results after completing the game. While this method permits learners to understand the relative distribution of their capabilities, learners noted that this method also permitted them to appreciate their own abilities. But in terms of feedback information, learners thought that if they could be reminded of the areas they need to improve on this would be more helpful for them to improve in those areas. So, if the feedback mechanism can provide feedback information which more clearly reminds learners, and more learning information then these might further enhance learning efficacy. For example, if we completely record learners learning progress, and provide direct indications during their learning of areas in need of improvement, and offer more suggestions and information these may prove more helpful for learners. Clear learning guidance may help enhance learners understanding of the learning contents. But this might also result in learner over-reliance on the guidance mechanism, and reduce their own critical thinking. This remains a question for further discussion.

The study findings indicate that the peer interaction mechanism exercises a positive impact and significant effects on learning. Thus, peer interaction can indeed help guide learners through peer-mediated learning. In the study process, we empirically demonstrated interactions between a relatively good learner and a relatively not so good learner. Their learning efficacy was higher than for that achieved among learners of equal strength in a group. The relatively poor student can rely on cohort mediation to effectively eliminate any doubts and obtain greater learning efficacy. Subjects also expressed that this method, allowed them to clarify their own thoughts, and complement each other in areas of relative weakness [11]. Though when both learners were faced with some concept or method which neither understood, they had to find additional help to engage in that learning. Thus this study believes that if the different groups could engage in discussion among themselves, this may help resolve the areas where the learners are lacking. Or we can use more feedback information which might allow the game-based feedback and peer interaction mechanisms to enjoy complementary interaction, for example by providing learner reminders to guide their learning to the relevant content and discussion.

Additionally, this study found that the interactive relations among learners may cause the game-based feedback and peer interaction to have no interaction. Since this study designed a game where learners compare their skills, the relations among the participating peers tend to be competitive ones. Thus learners tend to be more concerned with whether their skills are sufficient to succeed against others. Therefore in future studies the game design could deploy a cooperative game instead. This could allow learners to share in a common objective, and mutually aid each other to learn and enhance their learning results.

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From the discussions with the participants, we found that although the learners felt that the peer interaction mechanism could help them better elucidate the concepts and solve problems together, and enjoy deeper discussions in the more detailed areas, but they also felt this mechanism required much more time. As for the game-based feedback mechanism, subjects felt they were willing to use this method in the future to aid their learning. This study used random assignment of team members and group members, so it is possible that personal dislikes or unfamiliarity affected learning among the cohorts. If we can assign more familiar classmates to pairs and groups this may enhance their willingness to engage in peer interactivity. For future studies then we can incorporate these learning modalities into the classroom, so that among classmates digital learning cohorts can engage in interactivity enhancing their willingness to use these learning modalities.

6. Conclusions

This study combined game-based feedback and peer interaction mechanisms as adjunctive learning tools to aid learners. The game-based feedback mechanism relied on learning progress results to learn from the system while playing the game and thus to monitor their learning results from the feedback. The peer interaction mechanism relies on comparing the results of learners to affect the game results, so learners can compare their scores with those of another, playing the game with another and engaging in learning interactivity together. This study used an experimental design method with four different learning environments, to empirically compare game-based feedback and peer interaction impacts on learning efficacy and intention to use the modalities. The findings indicated that the peer interaction mechanism had significance on learner efficacy, while the game-based feedback mechanism had significance on willingness and intention to use these learning modalities.

Future studies should consider other game design characteristics in their educational design process, as the game design may exercise effects on the adjunctive learning mechanisms. Additionally it might be desirable to completely document learner progress in learning profiles, providing more detailed learner guidance and reminders or hints. Thus learners could not only see their learning capabilities, but also understand their learning processes in greater detail and appropriately adapt their learning strategies and methods.

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