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Abstract

Purpose – The purpose of this paper is to propose a game-based learning (GBL) content design model that replicates the two-dimensional Bloom cognitive process in GBL units. The proposed model, called the knowledge and cognitive-process representation (KCR) model, enables a game player to access three types of Bloom knowledge by allowing the learner to experience-related cognitive processes that can be replicated in the GBL units via appropriate representation approaches.

Design/methodology/approach – To validate the feasibility of the proposed KCR model, 14 GBL units for a Cisco-certified network associate (CCNA) certification training program were designed and installed on several servers. Players played the GBL units via internet browsers. According to the problem-solving theory, three game components, including a tool, feedback, and goal, are necessary for game playing and should be adopted to implement three sub-cognitive processes. A three-phase experiment was performed for one year. Subjects were university sophomores and a randomized block experiment design was implemented.

Findings – The experimental results show that, compared with a traditional web-based learning platform, the GBL platform is more efficient and it enables learners to achieve improved learning performance. In addition, most hypotheses support the fact that particular cognizance processes should be implemented by a specific representation approach in GBL. Finally, a KCR model for GBL content design is inferred to represent a cognitive process appropriately that can be referenced for both the digital content instructor and the game developer.

Research limitations/implications – Because the CCNA training material does not include meta-knowledge of Bloom knowledge type and the creation of the Bloom cognitive process, the KCR model should be further extended. In addition, others certification training materials (such as Oracle DBA, Java programmer) can be implemented on the basis of the KCR model for general validation as further research.

Practical implications – Players can acquire specific types of knowledge, such as factual knowledge, by experiencing a particular cognitive process, such as the "remembering & understanding" processes, which can be represented with a computer tool. The KCR model can provide both the instructor and the game developer with design recommendations and accelerate GBL content implementation.

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Originality/value – GBL is a learning platform that can stimulate a learner by improving the motivation to learn and the learning experience. To ensure high-learning performance, the learner should perform specific cognitive processes and acquire knowledge. This research proposes a content design model for GBL units that appropriately replicate the Bloom framework in a computer game.

Keywords E-learning, Human computer interaction (HCI), Computer game model, Applied learning, Interactive media, Game-based learning, Digital content design, Bloom cognitive process, IT certification training

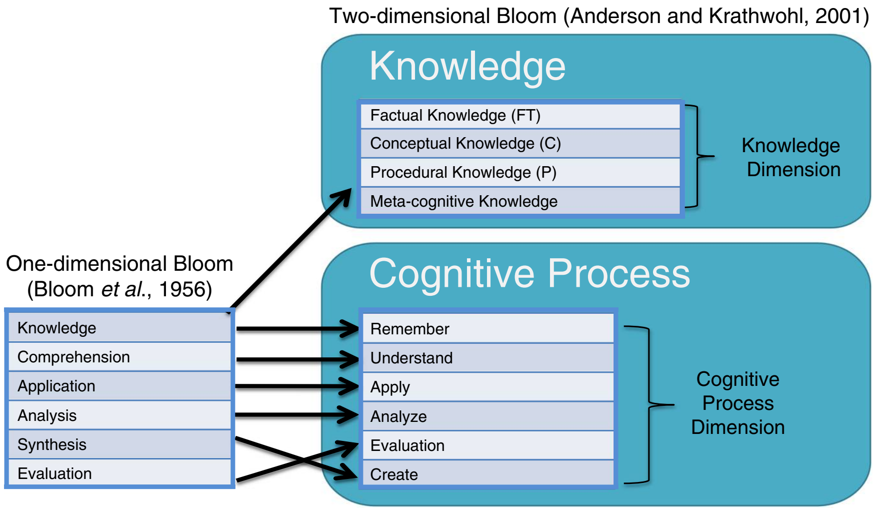
Paper type Research paper

1. Introduction

Instead of being viewed as an entertainment platform, many researchers regard computer games as an emerging distribution channel for digital content. In particular, a popular application of computer games is the integration of learning material and game playing, which is known as game-based learning (GBL), as discussed by Prensky (2003) and Dickey (2005). A number of researchers have applied GBL for expertise training in various domains. For example, some experiences in the medical field highlighted the usefulness of the GBL approach (Schmidt, 1983; Baroffio *et al.*, 1997; Carlile *et al.*, 1998; Morrison, 2004). In addition, Mooney and Bligh (1998) applied GBL (CyberIST) to medical education. Furthermore, Huang and Cappel (2005) applied web-based GBL to information system training. All of these applications support the finding that GBL resulted in superior learning performance, and actually stimulated learning motivation (Papastergiou, 2009).

Computer games are a typical experience-based medium that enables game players to gain experience in a specific episode via game playing (Swartout and Van Lent, 2003). To achieve better learning performance, the content design of each GBL unit is important (Robertson and Howells, 2008). The design model of digital learning material should be further adapted to the GBL content design because GBL is an emerging platform that differs from a traditional web-learning platform. In terms of content design of GBL, most previous studies provide preliminary directions to transforming e-learning content into "game-like" content. Specifically, the web-based learning materials are shifted to GBL content without considering the aspects of game narrative and entertainment. Dickey (2005) incorporated game design strategies into instructional design, such as focussed goals, challenging tasks, and affirmation of performance. However, these guidelines are too broad to be strictly followed. There should be an operational model that enables an instructor to incorporate cognitive processes and knowledge in GBL units using appropriate computer game components. Additionally, Philippe *et al.* (2006) emphasized that learning objectives should be fulfilled through a cognitive process experience. In other words, to ensure high-learning performance, the learner should experience specific cognitive processes and then acquire knowledge. This is similar to the two-dimensional (2D) Bloom framework, depicted in Figure 1, that dictates that specific knowledge should be achieved via a particular cognitive process (Anderson and Krathwohl, 2001). For example, the leaner can experience the cognitive processes of "remember" and "understand" to achieve factual knowledge. There should be a digital content design model that enables the cognitive process replication of GBL.

In this research, a content design model for GBL unit is proposed to appropriately replicate the Bloom framework in a computer game. As an experience-based medium (Nelson, 2002), GBL platform definitely appears to be an appropriate platform for constructing the cognitive process via the experience of a particular episode in a game



Source: Anderson and Krathwohl (2001)

Figure 1. Two-dimensional Bloom framework illustration

scenario. According to the 2D Bloom framework (Anderson and Krathwohl, 2001), to complete GBL content design, it is necessary to take both the cognitive process and knowledge type into consideration. The combination of computer game components (such as game tools and goals) is adopted to replicate a cognitive process (such as "remember and apply"). Then, that cognitive process enables the learner to acquire particular knowledge (such as facts or procedural knowledge) via game playing. Our proposed model can provide both the instructor and the game developer with design recommendations and accelerate the GBL content implementation. The remainder of this paper is organized as follows. Section 2 briefly reviews the previous literature. Section 3 presents the proposed knowledge and cognitive-process representation (KCR) model. The research methodology and experimental design is detailed in Section 4. Section 5 illustrates the GBL units according to the proposed model, and Section 6 discusses the statistical analysis results. Finally, Section 7 concludes some interest finding and proposes possible future research opportunities.

2. Related work

2.1 Computer game introduction and GBL applications

Computer games involve players interacting within an information technology to achieve specific goals and missions. In recent decades, numerous studies have examined computer games from various perspectives. Huizinga (1938/1955) and Caillois (1961) emphasize the central role of playing in human culture. Additionally, for example, some research has probed into game player behavior – Messerly (2004) discussed the effect of computer games on the school performance of computer science students. Most studies have examined the relationship between online games and internet fantasy violence (Williams and Skoric, 2005). A great deal of research has also been carried out on the issue of game player loyalty; researchers examined why people play computer games continuously and what their motivations for doing so (Choi and Kim, 2004; Hsu and Lu, 2004).

Among the various computer game applications, the applications of GBL have received a great deal of attention because researchers have explained the benefits of GBL, which can motivate and engage learners (Chen *et al.*, 2009; Garris *et al.*, 2002; Hwang and Wu, 2012). Some researchers have proposed frameworks (Barendregt and Bekker, 2004; Salen and Zimmerman, 2004; Amory, 2007) that provide the design directions for computer game design (Westera *et al.*, 2008). However, only a few studies have addressed the issues of GBL design and conducted a pedagogical review of a GBL implementation. For example, Amory (2007) presents a game object model (GOM) for the development and analysis of computer video games. There are six primary spaces in the GOM model, including: a game space, a visualization space, an elements space, an actor space, a problem space, and a social space, and relative elements for each space increment of the GBL unit. For illustration, goal formation and completion and competition are important elements of the game space in a GOM (Amory, 2007). However, as the 2D Bloom framework in Figure 1 shows, the learner should acquire a particular type of knowledge via a specific cognitive process (Anderson and Krathwohl, 2001). Therefore, a GOM can be further completed if the cognitive process can be replicated in the GBL design.

2.2 Training platform for information technology certification

Achieving information technology certification is a common goal for most IT-related professionals (Yang and Wang, 2009). There are over 100 kinds of IT-related certifications that vary from year to year (Zeng, 2004). Some researchers have attempted to integrate IT certification training into various platforms so as to increase certification pass rates. For example, Mulkey (2003) suggested integrating IT accreditation courses into formal, on-campus curriculum. However, most training is actually unsuccessful because learners do not actually comprehend the learning content; instead, they cram the correct answer to the certification questions into their short-term memory. A new platform is thus needed that is more attractive to teenage learners and that invokes motivation for learning and certification training. Prensky (2003) claimed that GBL provides learners with a more concrete experience that captures their attention and increases motivation, which is particularly important for teenager learners. GBL can provide users with a simulation arena that improves the certification training environment because computer games are a kind of an experience-based medium. Therefore, in this research, networking management training for Cisco-certified network associate (CCNA) certification was used as the experimental setting, and 14 GBL units were developed based on the proposed KCR model.

3. Proposed KCR model

As an experience-based medium, computer games typically have a mission-oriented content design (Nelson, 2002). In game playing, the player is assigned a mission and is required to complete it to finish the game. We can regard the game-playing process as being similar to the problem-solving process. From a problem-solving theory perspective, a computer game should provide players with at least three components – tools, feedback, and goals – to assist them in completing their missions (Choi and Kim, 2004). A "goal" is the milestone that players attempt to complete. For example, in a shooting game, the goal may be rescuing all of the hostages from the bad guys. "Feedback" is a kind of reinforcement in that a player's predetermined, desirable behavior is rewarded (positive feedback). In contrast, undesirable behavior results in punishment (negative feedback). "Tools" are instruments such as knives, capes, and magic, which players utilize to achieve their goals. Goals, feedback, and tools are the three major components of any computer game. Problem-solving theory dictates that it is necessary to provide these three components in all computer games. Therefore, in the KCR model, we have attempted to replicate these Bloom cognitive processes via using these three components.

3.1 KCR model for GBL design

The proposed model intends to present various kinds of Bloom knowledge into computer games and then replicate cognitive processes as the game playing. For CCNA certification training, except for the meta-cognitive knowledge, this research involves three sub-Bloom knowledge categories: factual (FT), conceptual (C), and procedural knowledge (P). Accordingly, for the cognitive process dimension, there are three cognitive processes. This research aggregated "remembering & understanding" and "applying & analyzing" into two sub-cognitive processes. The "evaluated" process is taking into consideration as the third cognitive process, as shown in Figure 2. According to problem-solving theory, three game components – a tool (T), feedback (FB), and a goal (G) – are necessary for game playing, and these three components seem to be the feasible approaches to implement three sub-cognitive processes for GBL design.

The proposed KCR model is shown in Figure 2, and an experiment was carried out to validate these combined representations for the GBL unit design. For the

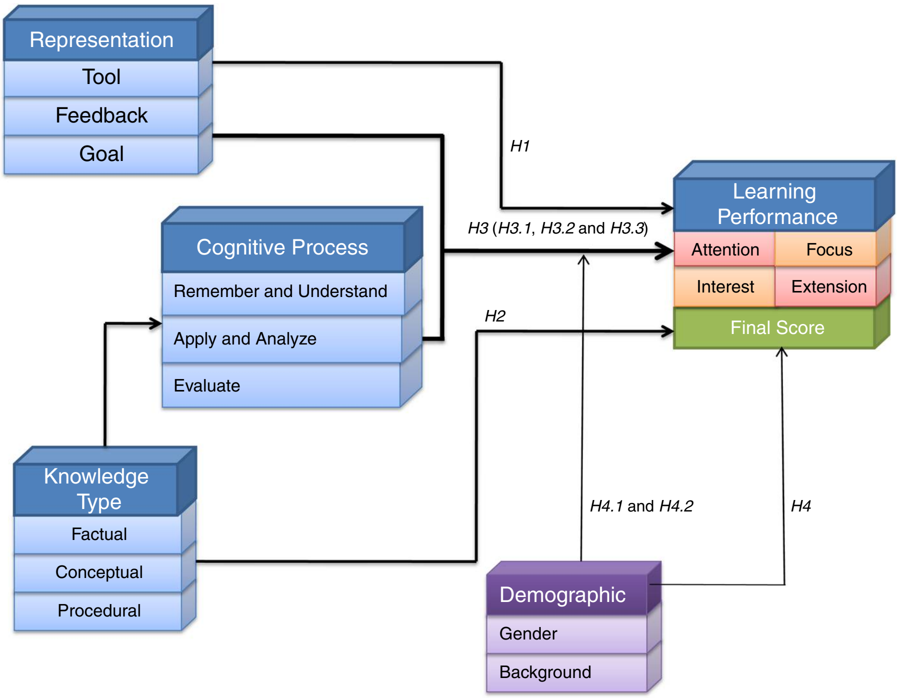


Figure 2.
Three dimensions for implementing certification training in computer game

independent variable, two indicators evaluate the GBL learning performance. First, a final exam score of the participant was adopted as an indicator. Second, according to the Bloom framework, a learner can acquire related knowledge incrementally via experiences of a particular cognitive process. Therefore, evaluating the cognitive psychology status of the learner is another important indicator. Similar to the advertisement diffusion effect, learning performance should be a series of psychological reactions. As shown in Figure 2, for cognitive psychology status evaluation, four effects, namely, attention (A), interest (I), focus (F), and extension (E), are also collected via a questionnaire to estimate the learning performance as the second indicator. Then, to ensure the content validity of the second indicator evaluation, all items were adopted from prior literatures, with some minor adjustments necessary to adapt to our research context. For the attention effect, two items were designed to measure the learner's awareness about GBL content appearance (Ha, 1996). For the interest effect, the learning interest and the learning desire of a learner, such as GBL usefulness and GBL entertainment, were estimated with another two items (Ha, 1996; MacKenzie *et al.*, 1986). Then, two items measure the focus effect of the learning behavior, such as the sustained learning effort, and the voluntary learning behavior. Finally, for the extension effect, the learner's learning motivation is evaluated via the GBL learning unit using five items.

3.2 Research hypotheses

All three GBL representations, including tools, feedback, and goals, differed significantly from one another. For instance, the frequencies of the representations appearing in GBL differed from one another. Tools can appear anytime because players must complete their game mission by using a tool. In contrast, a computer game's goal might appear just once as a player achieves each mission. However, users desire to clear the mission then goal achievement. The game tool is only an operator and may be meaningless. Thus, this research assumes that different GBL representation formats result in different learning results. The first hypothesis is proposed as follows:

H1. Different game representations result in different learning performance.

In addition, the different types of knowledge in Bloom's revised taxonomy are distinct. For instance, factual knowledge is not only different from procedural knowledge, but there is also a sequential relationship. It is difficult to ask a user to understand advanced concepts before he or she gains basic knowledge. Thus, this research also seeks to discover if any types of knowledge (factual, conceptual, or procedural) are dedicated to a specific game unit and proposes the second hypothesis:

H2. Different knowledge types result in different learning performances.

Then, to achieve better learning performance, we further discuss the best combinations of representation approaches and cognitive processes. The combination representation of computer tools and feedback is adopted to implement both the "remember & understand" and the "apply and analyze" cognitive processes. Because players are expected to use game tools frequently during game playing, tools are available to assist game players in remembering factual and conceptual knowledge. In other words, this factual and conceptual knowledge would be presented as a kind of game tool in a GBL unit, and the player should thus utilize such a tool to complete a mission. We inferred that such a combination of representations can assist the player in remembering and applying related knowledge. Additionally, feedback is thought to be the most feasible

GBL representation to implement the "apply & analyze" cognitive process. This is because feedback provides a certain amount of interaction. Thus, a game player would receive positive (or negative) feedback if a particular conceptual knowledge is appropriately (or inappropriately) applied to problem solving. Finally, the goal is thought to be the most feasible representation of the evaluation cognitive process because a learner experiences several cognitive processes that are similar to computer games, which is the finally reached part. Thus, this research forms the third hypothesis, and three sub-hypotheses:

H3. Interaction effects exist between game representation and cognitive process implementation.

H3.1. To achieve better learning performance, a combination GBL representation of tool and feedback is the best for the "remembering & understanding" cognitive process implementation.

H3.2. To achieve better learning performance, a combination GBL representation of feedback and goal is the best for the "applying & analyzing" cognitive process implementation.

H3.3. To achieve better learning performance, a goal GBL representation is the best for the "evaluating" cognitive process implementation.

Finally, considering that most computer game players are teenage males (Messerly, 2004) and that game playing also requires skill in operating information technology, this research discusses whether or not GBL performance is affected by demographic variation, including gender and student background. Therefore, the fourth hypothesis and the sub-hypotheses are also verified:

H4. No integration effects exist between demographic and learning performance.

H4.1. No interaction effects exist between gender and learning performance.

H4.2. No interaction effects exist between background and learning performance.

4. Research methodology and experiment design

A three-phase experiment was performed to test the KCR model. Subjects were university sophomores. Representation was ensured because most computer game players are teens and students (Messerly, 2004). The subjects were sampled from two backgrounds: IT-related and IM-related. For the IT-related participants who were majoring in information technology, the networking management course is a required course in their course design. In contrast, for the IM-related participants who were majoring in information management, the networking management course is an elective. This study adopted a randomized block design. Three major factors were considered as independent variables: knowledge type (three types, including FT, C, and P), cognitive process (three aggregated processes), and representation form (three approaches). Demographic data (gender and background) represented the block variable.

In total, 14 GBL game units were designed via flash and installed on several servers. Players played the GBL units via internet browsers. The difficulty of the GBL units was set to the medium level, because we hoped that all participants would finish the GBL unit learning and achieve their goals. No special skills were required. In addition, to validate the efficiency of the proposed KCR model, two units (Units 3 and 4) were selected as the control units. These two units were implemented in both the web-based and GBL formats according to the KCR model. The contents of Unit 3 (about OSI) and Unit 4 (about TCP/IP) are related to networking protocols that are basic networking concept and similar to each other. Therefore, these two units were appropriately selected as control units to avoid the interference effect from the knowledge type. All participants must experience the learning material in both the GBL and web-based platforms. Also, to avoid the memory effect from the previous experience, the sequence for these two units carefully arranged. For example, a subject participated in a GBL platform before the web-based platform for Unit 3. Then, the same subject experienced the web-based platform before the GBL platform for Unit 4.

The regular experiment consisted three phases, as listed in Table I. Similar to the prior test, the random block design of participants was implemented according to the experimental results of phase I. Also, in phase I, more than 80 percent of the players completed the GBL units without difficulty. The main experiment was conducted in phase II over the course of six months. Finally, two information indicators – the final exam score of participant and the questionnaire feedback about the AIFE effects – were collected in phase III for further analysis.

5. GBL unit illustrations

To examine the KCR feasibility, 14 GBL units are implemented, as listed in Table II. The flash GBL units were designed in support of Cisco networking certification training.

Experiment phase	Implementation time	Experiment description
Phase I	One month as a trade-off before phase II. For such a period, the memory effect was weakened but subject preferences remained unchanged	Subjects were required to take a preliminary networking exam, which measured the fundamental networking knowledge and computer game preference of a subject. Each subject was assigned a score for phase II random block allocation
Phase II	The experiment was performed when the subject was available. Each GBL unit lasted one week. After finishing each game stage, the players took 5-10 min to complete a questionnaire and then proceeded to the next GBL unit until they finished playing all the GBL units. It took six months to complete the all experiments of phase II because each unit, including learning content and game playing, took at least one to two weeks to complete	This was the main phase. Each subject was required to finish 14 GBL units involving three knowledge types and experience multiple cognitive processes. In addition, to validate the GBL's efficiency, two units, Unit 3 (OSI protocol) and Unit 4 (TCP/IP), were selected and implemented in both the web-based and GBL formats. The allocation rule was to maintain the most constant total participant preference scores. A subject would be further allocated to play Unit 4 GBL iff (if and only if) he or she was assigned to view the web-learning content of Unit 3. In contrast, a subject would be allocated to play the Unit 3 game and the browser web content of Unit 4
Phase III	Two weeks following phase II for each unit	The selected subjects were interviewed to measure their feedback

Table I.
Three-phase experimental design

There are six training courses about basis networking concept, including networking introduction (U1), Ethernet introduction (U2), open standard interface (OSI) introduction (U3), TCP/IP training (U4), IP address (U5), and subnetting (U6).

According to Bloom's framework, Table II tabulates all six courses and then implements them according to tool, feedback, and finally goal. Each course is further divided into two to three sub-units, 14 GBL units in total. To illustrate, Unit 2 mainly introduces the concept of the Ethernet, which contains: (2.1) the introduction to the Ethernet. Learners will experience "remember & understand" cognitive processes to learn factual knowledge regarding the Ethernet. Then, the content of (2.2) is the application of (2.1) on Ethernet deployment, which connects equipment via straight-through, crossover, and rollover cable. Finally, learners should be equipped with the ability to compare the pros and cons of each method of building an Ethernet network. Learners will experience the evaluation stage of the cognition process.

Game players can access these GBL units via internet browsers and then click on questionnaire answer links to obtain feedback on their learning performances. For each unit, the game player should go through knowledge tuition before playing. Figure 3(a) depicts the menu of the GBL module's front page. The user can click on networking concepts tuition for knowledge achievement. Figure 3(b) depicts the networking topology knowledge of Unit 1.1.

Based on the KCR model, for example, in the curriculum of CCNA certification (as shown in Figure 4), a game tool represents Ethernet knowledge. Players have to correctly match all networking cables (such as the cable type of 10 Base 2 in Figure 4) with the appropriate connectors (such as the connector type of the BNC connector in Figure 4) and then complete the mission in Unit 2.1. Additionally, game feedback guides the player to make the correct cable connection, as shown in Figure 5. Players must select feasible equipment for configuring the networking cable, such as crossover or straight-through networking cable. If a learner makes an incorrect selection, a score deduction is given as a punishment and negative feedback is given (as shown in Figure 5(a)). In contrast, a bonus score is given as a reward for a correct selection (as shown in Figure 5(b)).

6. Statistical analysis of experimental results

To collect information related to psychology and learning performance, the questionnaires were designed by modifying the questionnaires found in the literature. All items proved to have good reliability (the average Cronbach's

Knowledge type	Remember & understand	Apply & analyze	Evaluate
Factual	1.1 Networking topology 2.1 Ethernet introduction	2.2 Ethernet deployment	1.3 Topology comparison
Conceptual	3.1 OSI introduction 4.1 TCP/IP vs DoD	1.2 Advance topology 3.2 OSI functions 4.2 TCP/IP functions	2.3 Ethernet comparison
Procedural	5.2 Hierarchical IP address structure	5.1 Binary-hexadecimal conversion 5.3 Subnetting 6.1 VLSM	–

Table II. Bloom's revised taxonomy: taking the basic CCNA course as an example

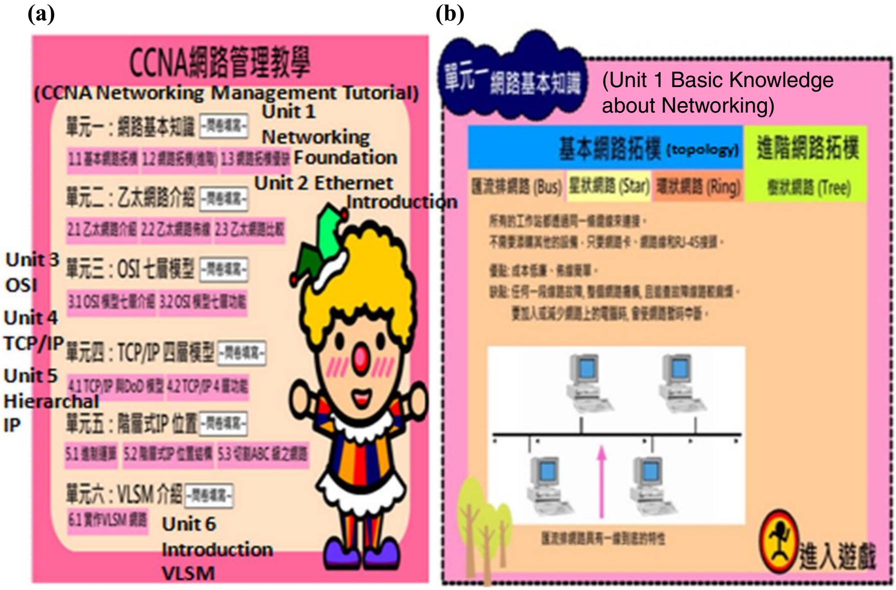


Figure 3. Computer game front page and networking management knowledge tuition

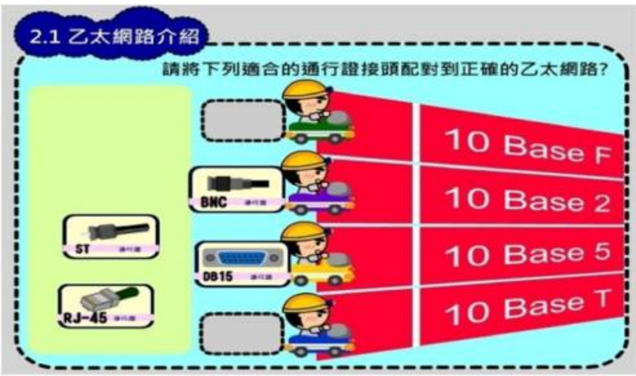


Figure 4. Unit 2.1: tool representation demonstrations

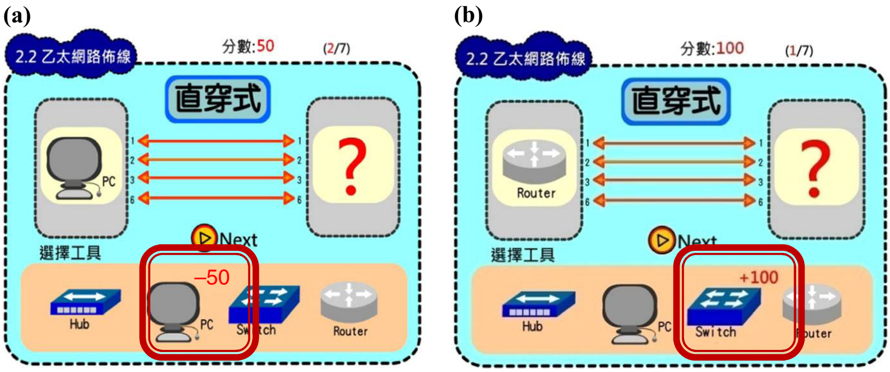


Figure 5. Units 2.1 and 2.2: demonstration of tool and feedback representation

Notes: (a) Negative feedback: score deduction; (b) positive feedback: bonus score

α reliability test is above 0.7). In the experiment, all subjects were considered invalid samples until they completed all 14 games of six units and answered all questionnaires. The average return ratios of each unit is 79.39 percent. The lowest one is Unit 6 (approximately 70 percent). However, an invalid subject may bypass different game units. Thus, only approximately 60 percent of subjects can be regarded as comprising a valid sample. There were 117 valid subjects who completed all six units experiment. The distributions of valid subjects are listed in Table III. The majority of the valid subjects were male (about 65 percent), which is consistent with the findings of the previous survey (Messerly, 2004).

Consequentially, two learning performance measurement indicators were adopted in this research. For the first indicator, the subject exam score was then transferred into a Likert five-point scale for consistent analysis. In terms of the second psychological indicator, questionnaires were implemented to collect learning performance information related to the attention (A), interest (I), focus (F), and extension (E) effect of the subject. Additionally, an integral measurement perspective, called AIFE-avg, which gives the average scores of attention, interest, focus, and extension, represents the synthetic learning performance. Table IV lists the means of the dependent variables according to the main KCR model experimenters and block variables. For the KCR experimenters, such as knowledge type and representation, both two indicators, the AIFE and the final exam scores, are above 3.5 points and deserve to further discuss. In addition, compared with the web-learning platform, the GBL platform yielded superior results for all the AIFE dimensions (the F-value was 3.846 at 99 percent level of significance). Therefore, as expected, GBL can achieve better learning performance and should be analyzed further.

6.1 Analysis of the main effects of representation and knowledge type

A four-way MANOVA was performed on the variables (AIFE) shown in Table IV that exhibited significant knowledge type (the Wilk's λ was 0.971 at a 99 percent level of significance) and representation effect (the Wilk's λ was 0.963 at a 99 percent level of significance). In particular, as shown in Table IV, for both knowledge type and representation, the interest effect was significantly different at 99 percent level. Therefore, both *H1* and *H2* were supported. The representations produced different learning and effectiveness, particularly in relation to interest, extension (at a 99 percent level of significance level), and attention effects (at a 95 percent level of significance).

Except for the focus effect, the effect ranking of representation approach was T/FB, FB/G, and T/FB/G, as shown in the Scheffe test listed in Table V. The differences in the effect between T/FB and T/FB/G were significant at $p = 0.001$ to $p = 0.003$. More interesting was the focussed learning's effect representation rankings of FB/G, T/FB, and T/FB/G for the Scheffe tests results, as shown in Table V. Therefore, *H1* was supported. This may have resulted from the fact that the knowledge exposure rates of the three representations in the game followed the order: T/FB, FB/G, and T/FB/G. Therefore, with regard to the interest and extension effect, the ranking of representation

Dimension	Cluster	Subjects
Gender	Female	41
	Male	76
Background	IT	49
	IM	68

Table III. The distribution of valid subjects

Table IV.
Means and four-way MANOVA analysis result in different settings

Dimension (Wilk's λ)	Cluster	Attention Mean	Attention Sig.	Interest Mean	Interest Sig.	Focus Mean	Focus Sig.	Extension Mean	Extension Sig.	AIFE-score Mean	AIFE-score Sig.	Score Mean	Score Sig.
Platform	Game	3.84	0.116	3.62	0.003**	3.65	0.000***	3.74	0.000***	–	–	–	–
(0.000**)	Web	3.71		3.35		3.39		3.41					
Gender	Female	3.64	0.000***	3.35	0.000***	3.52	0.000***	3.57	0.000***	3.52	0.000***	4.34	0.000***
(0.000**)	Male	3.98		3.80		3.74		3.88		3.85		3.88	
Background	IT	3.98	0.007**	3.78	0.002**	3.75	0.014*	3.93	0.000***	3.86	0.000***	4.12	0.003**
(0.000**)	IM	3.75		3.51		3.58		3.63		3.62		4.04	
Knowledge type	FT	3.88	0.610	3.74	0.009**	3.62	0.193	3.84	0.834	3.77	0.595	4.02	0.420
(0.000**)	C	3.83		3.67		3.67		3.74		3.72		4.06	
	P	3.83		3.66		3.66		3.69		3.67		4.12	
Representation	T/FB	3.95	0.026*	3.76	0.000***	3.63	0.504	3.89	0.000***	3.81	0.002**	4.00	0.687
(0.000**)	FB/G	3.81		3.64		3.73		3.71		3.72		4.19	
	T/FB/G	3.77		3.52		3.65		3.67		3.65		4.07	

Notes: *,**,***Significant at $p = 0.05$; $p = 0.01$; and $p = 0.001$ levels, respectively was T/FB, FB/G, and T/FB/G. On the other hand, too frequent interruption during the game-playing process (such as a tool) leads a low focus effect on the learner, and thus, the representation ranking became FB/G, T/FB, and T/FB/G for a focus learning effect. In addition, we infer that because the combination approaches of T/FB representations are applied for fundamental cognitive process replication, the AIFE learning performance is better than the advanced cognitive process, which was implemented via FB/G and T/FB/G combination representations.

Consequently, the main effect of knowledge type was analyzed in Table IV that computer games are actually appropriate for specific knowledge types, particular in terms of the improvement in the interest effect. Therefore, *H2* was supported. In relation to the interest effect, the effect ranking of knowledge type is FT, C, and P for the Scheffe tests results (see Table V). The differences in effect between FT and P were significant at the $p = 0.05$ level. We can infer that factual knowledge is more appropriately implemented in a GBL platform and can simulate better learning interest in subjects. In addition, we inferred that factual knowledge is a fundamental knowledge type and that it involves the "remember & realize" cognitive process, which is easier than advanced cognitive processes, such as the "apply & analyze" cognitive process. Therefore, GBL is more appropriate for basic learning unit implementation and fundamental cognitive process replication.

Finally, for the interference effect analysis of the block variables, a four-way MANOVA was performed on the variables (AIFE), as shown in Table IV, that exhibited a significant effect for gender (the Wilk's λ was 0.919 at a 99 percent level of significance) and user background (the Wilk's λ was 0.970 at a 99 percent level of significance). Therefore, *H4.1* and *H4.2* was supported. For the sub-hypothesis test of *H4.1*, there is an interesting finding regarding the gender effect. For the second indicator (named AIFE), the male subjects achieved a higher learning performance than the female subjects. However, for the first indicator (the final exam score), the female subjects achieved a higher learning performance than the male subjects. We can conclude that the GBL platform indeed improved the learning motivation (particular for male subjects). For the final exam score indicator, the analysis result is consistent with our interview results. The female subjects claimed they spent a great deal of time preparing for their final exams, which might explain why the female subjects achieved higher exam scores than the male subjects. For the sub-hypothesis test of *H4.2*, as expected, the subjects with an IT background achieved better learning performance than the subjects with an IM background for both indicators. We can infer that the networking management course is a required course for the IT background subjects, so these subjects may pay more attention to this issue.

Independent variable	Attention	Interest	Focus	Extension	AIFE-avg	Score
Representation	T/FB > FB/G > T/FB/G (0.116)	T/FB > FB/G > T/FB/G (0.003)**	FB/G > T/FB > T/FB/G (0.002)**	T/FB > FB/G > T/FB/G (0.001)***	T/FB > FB/G > T/FB/G (0.020)*	FB/G > T/FB/G > T/FB (0.328)
Knowledge type	FT > C > P (0.723)	FT > C > P (0.012)*	C > P > FT (0.775)	FT > C > P (0.776)	FT > C > P (0.548)	P > C > FT (0.846)

Notes: *,**,***Significant at $p = 0.05$; $p = 0.01$; and $p = 0.001$ levels, respectively

Table V. Post-tests of game representation and knowledge type

6.2 Analysis of the interactions of knowledge types and representation forms

To validate the research goal, the interaction of knowledge types and representation were examined and found to be significant in Table VI at the $p = 0.01$ level. The most interesting finding was the attention effect because it did not emerge significantly until the interaction was analyzed. We can infer that a particular knowledge type matches a specific representation form appropriately and can achieve level learning performance. Therefore, *H3* was partially supported.

For the attention effect, which is the only significant one in Table VI, the Scheffe test result in that the conceptual is appropriate represent via the T/FB approach of GBL and improve the learning attention effect. Therefore, *H3* was partially supported. On average, factual and conceptual knowledge were suitable as a representation of tool and feedback in GBL, especially to attract attention or interest and extension. Moreover, if conceptual knowledge is presented, the T/FB combination is a recommended representation to attract attention.

Finally, in phase III, ten subjects were selected and interviewed for GBL platform feedback collection. As expected, most players claimed that GBL is more interesting than a traditional web page glance through. As the summary of the interview results, on average, subjects usually spend 2-2.5 h a week playing each unit's game. Some players even go through the material tuition three times to obtain the correct answer and complete the specified GBL goal. We infer that the learning interest effect is the most significant learning effect for both knowledge type and representation factor, as shown in Table IV. In addition, most subjects mentioned that they discussed collecting more game information with classmates. Therefore, the GBL platform can actually stimulate a learner's motivation and desire for extending learning. In addition, almost all subjects gave positive feedback regarding GBL content design. Furthermore, some were willing to take advanced networking management courses and further realize CCNA certification. Finally, there were also some comments regarding GBL design, such as when players believed that some GBL units were too quick to complete the game's mission and intention. In addition, they felt that some units were too obvious to foster an interest computer games. These comments can be referenced for further study.

Dimension	F-value (sig.)	Attention (sig.)	Interest (sig.)	Focus (sig.)	Extension (sig.)	AIFE-avg (sig.)	Score (sig.)
Interaction among gender, background, and knowledge type	1.231 (0.265)	0.568 (0.567)	0.275 (0.760)	3.282 (0.038)*	0.811 (0.455)	0.951 (0.387)	0.480 (0.619)
Interaction among gender, background, and representation	1.624 (0.094)	1.178 (0.308)	0.695 (0.499)	5.768 (0.000)***	2.816 (0.060)	2.924 (0.054)	0.011 (0.989)
Interaction between knowledge type and representation	2.868 (0.003)**	3.809 (0.046)*	1.423 (0.241)	2.264 (0.104)	0.349 (0.706)	0.300 (0.741)	0.274 (0.761)
Interaction among gender, background, knowledge type, and representation	0.298 (0.982)	0.039 (0.962)	0.012 (0.988)	0.043 (0.958)	0.492 (0.612)	0.063 (0.939)	0.197 (0.821)

Notes: *,**,***Significant at $p = 0.05$; $p = 0.01$; and $p = 0.001$ levels, respectively

Table VI. Interaction analysis among block variable

7. Conclusion and future work

The computer game is an emerging mass medium; it is now regarded as an electronic platform instead of an entertainment medium. GBL applications are popular but lack a reference model for GBL content design guidelines. How to replicate the cognitive process that enables a learner can receive related knowledge incrementally in GBL has also received less attention. In this research, we proposed a model for GBL content design reference, called the KCR model. Because GBL is a kind of experience and mission-origin medium, according to problem-solving theory, KCR adopts three representations, including tool, feedback, goal, and their combinations, to implement GBL content design. In the KCR model, in accordance with problem-solving theory, particular knowledge content and cognitive process is represented by specific computer game tools, feedback, and goals in game design. KCR was validated via a CCNA certification training experiment.

As the experimental results revealed, to achieve improved learning performance, specific cognitive processes are appropriately represented with a particular representation that enables learners to achieve various types of knowledge. Players can achieve specific knowledge types, such as factual knowledge, via the experience of a particular cognitive process, such as ”remembering & understanding” processes, which are represented via a computer tool. KCR can provide instructors with recommendations to replicate 2D Bloom knowledge and cognitive processes in computer games to achieve the desired learning performance. Further, according to the interview feedback from the participants, we believe the GBL can be used as the platform for remedial teaching because GBL can increase the learner’s desire to learn and can be expected to improve learning performance.

More certification training materials, such as Oracle DBA training or ERP certification can be implemented on the basis of the KCR model for general validation as further research. In addition, because of the CCNA training material characteristics for the 2D Bloom framework, neither the meta-knowledge of the Bloom knowledge type nor the creation of the Bloom cognitive process are allocated in the KCR model. Finally, according to Caillois (1958, 2001) provides a useful classification and analysis of different types of games (including: agon, alea, mimicry, and ilinx) and ways of playing (such as paidia and ludus), result in KCR model may be adapted to different types of computer game. Additionally, according to our interview results, the flow experience of game player (Csikszentmihalyi, 1975) can be further discussed. In the future, we will engage in related discussion and KCR extension model revision.

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