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以資訊回饋與科技接受模式觀點探討影響大學學生採用遊戲式學習系統之關鍵因素:以電子化資料庫正規化教學為例

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摘要

關於影響使用遊戲式學習系統來提昇學習成效之關鍵因素為何,在不同教學領域中仍有些許爭議。此外,同時檢驗資訊回饋與學習動機對於學習者使用遊戲式學習系統之態度與學習成效的影響之過往研究仍然稀缺。因此,透過參考資訊回饋、學習動機、與科技接受模式之觀點,本研究發展並實證一個可以用來理解遊戲式學習系統之效果的理論模型。本研究使用收集自 322 位受訪者之資料來驗證本研究所提出之理論模型。研究結果顯示,資訊回饋與學習動機會透過顯著影響學習者對於遊戲式學習系統的認知有用性與認知易用性、來顯著正向影響學習者之認知學習成效。與研究結果相關之學術貢獻與實務貢獻亦已加以詳細論述。

關鍵詞: 遊戲式學習系統、科技接受模式、 資訊回饋、學習動機、資料庫管理

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Investigating Key Factors Influencing College Students' Adoption of Game-based Learning System Based on The Perspectives of Information Feedback and TAM: An Example of Database Normalization

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Abstract

Critical factors that influence the value of online game-based learning systems (GBLS) for enhancing learning effectiveness remain debatable across different learning contexts. Additionally, studies that simultaneously examine the effects of information feedback and learning motivation on learners' perception regarding using the GBLS and their learning effectiveness are scarce. Therefore, based on the perspectives of information feedback, learning motivation, and technology acceptance model, this study develops a research model for comprehending the effectiveness of GBLS. Data collected from 322 respondents was analyzed to validate the research model. The results showed that information feedback and learning motivation significantly influenced students' perceived usefulness and perceived ease of use regarding the GBLS, which, in turn, positively influenced perceived learning effectiveness. Implications for theory and for practice are discussed accordingly.

Keywords: Game-based learning systems, Technology acceptance model, Information feedback, Learning motivation, Database management

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1. INTRODUCTION

The adoption of information-technology (IT) enabled game-based learning systems (GBLS) in higher education settings has become more and more popular and are intensively discussed in recent years. The use of GBLS is considered to be capable of increasing students' learning motivations and as an effective assisting tool for facilitating their learning performance. However, various challenges remain for the design and implementation of GBLS. For example, because students tend to perceive learning activities enabled by the GBLS as informal activities and may not want to devote too much efforts into participating in such activities and translating what they learn via using the GBLS into disciplinary knowledge (Martin, Silander, & Rutter 2019).

There have been a significant number of prior studies of the adoption of the GBLS in the educational settings of elementary and high schools (e.g., Cheng et al. 2017; Fidan & Tuncel 2019; Homer et al. 2018; Hwang et al. 2016; Iten & Patko 2016; Kao, Chiang, & Sun 2017; Liao, Chen, & Shih 2019; Papadakis, Kalogiannakis, & Zaranis 2018; Sung et al. 2017; Vasalou et al. 2017; Zhang 2016) and higher education (e.g., Barr 2017; Brom et al. 2017; Buckley & Doyle 2017; Cheng et al. 2014; Jia & Eder 2009; Liu, Wang, & Huang 2023; Liu, Wang, & Lee 2021; Novak & Tassell 2015; Park et al. 2019$_b$; Tao, Cheng, & Sun 2009). Additionally, prior studies constantly recognize information feedback and learning motivation as a complementary set of key factors for evaluating how learners' use of GBLS may facilitate their learning effectiveness (Göksün & Gürsoy 2019; Moizer et al. 2019; Ninaus et al. 2019; Park et al. 2019a; Liu et al. 2021; Wang, Lin, & Lu 2023). However, there is a lack of GBLS studies that specifically investigate the relationships among GBLS-provided information feedback, learning motivation, technology-acceptance-related factors, and the perceived learning effectiveness of GBLS users. Consequently, this study is conducted with intent to address this particular research gap.

It is argued in the literature that the current electronic learning (e-learning) solutions still suffer from one or multiple of the four primary drawbacks. These drawbacks include focusing primarily on technology rather than on offering instructional support and support of learners' needs, the provision of boring and insufficient structured learning materials (e.g., structured electronic documents), forcing learners to learn by using poorly designed and complicated human-computer interaction mechanisms, and concentrating on the replication of facts and information rather than on challenging the learners and encouraging active interactions with the knowledge (Pivec 2007). Regarding the use of GBLS, although it is usually fun when

people immerse in an imaginary world created by game, developing an understanding of how and to what extent GBLS can have the potential to facilitate student learning in the context of higher education is a critical issue (Ebner & Holzinge 2007; Liu et al. 2021). Additionally, few studies have explored what needs to include in the pre-game, in-game, and post-game instructions (i.e., information feedback) in order to assist learners to translate what they learn from the game into critical domain knowledge that they intend to learn (Liu et al. 2021; Martin et al. 2019; Wang et al. 2023). Overall, the discussion above implies the necessity of examining the effects of technology-adoption-related factors and information feedback (e.g., the type of information provided and the manner such information is presented during the progress of learning activities enabled by the GBLS), and the learning motivation for facilitating learning effectiveness from a student's perspective.

Based on the results of our literature review, we identify five primary conceptual dimensions that are associated with students' behavior regarding the use of GBLS, which include information feedbacks, learning motivation, technology acceptance orientation, and perceived learning effectiveness. The well-known framework of the technology acceptance model (TAM) and the information feedback theory are adopted in this study as theoretical bases to develop a research model that explains the development of students' learning effectiveness resulted from the use of GBLS in the context of higher education. Therefore, the primary objective of this study is to seek answers to the following research question:

RQ: *How do information feedback, technology-adoption-related factors, and learning motivation contribute to students' learning effectiveness in the context of GBLS use in higher education?*

To achieve this purpose, this study develops and empirically validates a theoretical model that specifically investigates how students' learning motivations and the different forms of information feedbacks provided by GBLS affect the students' evaluation regarding the usefulness and the ease of use of the GBLS and, consequently, enhance their perceived learning effectiveness by integrating the perspectives of the TAM and the information feedback theory. The results of the validation of the proposed research model will provide us with an understanding of how to design a high-quality GBLS that provides high-quality information feedbacks to students by presenting useful messages in an appropriate format at the right place at the right time, which may lead to the development of favorable evaluation regarding the GBLS and, in turn, facilitate the students' learning effectiveness.

2. LITERATURE REVIEW

Given the low acceptance rate of the GBLS in the contexts of higher education, this study aims to explain and predict the adoption of such systems by adopting TAM (Davis, Bagozzi, & Warshaw 1989) to address the technological considerations of the potential GBLS users, and evaluate the influence of the use of GBLS on their perceived learning outcomes (O'Neil, Wainess, & Baker 2005). Additionally, it is argued that the use of GBLS have the potential to enhance students' learning motivations (Garris, Ahlers, & Driskell 2002; Fidan & Tuncel 2019; Park et al. 2019$_b$), which is one of the main drivers of active learning behavior (Hsu & Huang 2006). Finally, the significant effects of various kinds of information feedbacks on the quality of decision making is evident in the literature, we thus consider it to be one of the key conceptual dimensions that impact how the GBLS can benefit the users in terms of facilitating their learning effectiveness. Therefore, in the subsequent sections, literature that is related to the GBLS, technology acceptance model, information feedback, learning motivation, and perceive learning effectiveness will be reviewed in order to address the significance of the findings of this study.

2.1 Game-based Learning Systems (GBLS)

It is argued that playing multiplayer online games can help individuals develop abilities to construct identity and build social relationships in their personal lives (Malegiannaki & Daradoumis 2017; Turkle 1995). This argument implies that the best way for one to know oneself is to play games because one tends to freely express what he or she is really like in the virtual world. Additionally, individuals who play multiplayer computer games can interact with one another to work together to resolve problems in order to advance in the games, which is a very intense but entertaining experience for game players. By taking advantages of those features of computer games, GBLS can be used as a platform for facilitating learning, in which learners can collaboratively solve problems, overcome challenges, or even compete with others to increase their learning motivation and learning performance (Liao et al. 2019; Park et al. 2019$_b$; Prensky 2001).

Processes of GBLS can encompass educational objectives, and this approach are believed to have the potential to make the learning of academic subjects more learner-centered, easier, more enjoyable, more interesting and, thus, more effective (Papastergiou 2009). Additionally, the benefits of learning through GBLS are abundant because individuals' gaming experience is closer to their real-life experience (e.g., problem-solving, taking chances, and interpersonal competition) compared to that of using traditional educational media (Ebner & Holzinger 2007).

In the context of higher education, educational practices that are supported by various forms of digital games have been proven to be effective in terms of enhancing college students' learning motivations, encouraging active engagement to educational activities, and facilitating their development of desirable skills and competences they are expected to acquire before graduation (Barr 2017; Brom et al. 2017; Cheng et al. 2014). Additionally, by focusing on the progress of a well-designed digital games, students can increase their abilities to suppress irrelevant, distracting information and, consequently, improve their working memory capabilities for achieving better learning performance (Novak & Tassell 2015). Doolittle, Bryant, & Chittum (2015) also highlight the importance of understanding the effects of the manner to which information is given (e.g., appropriateness of segmentation of information) in GBLS on learners' learning performance.

The practices of gamification have been applied to and proven to be effective in educational settings for various advanced subjects in the literature, including management, information technology, communications, security, healthcare, and sustainability, as summarized in the work of Buckley & Doyle (2017). However, a number of prior studies that review the progress of studies of the use of digital games in various subject areas in the contexts of higher education reveal two primary issues that are relevant to the research foci of the current study (Boyle et al. 2016; Caballero-Hernandez, Palomo-Duarte, & Dodero 2017; Kordaki & Gousiou 2017; Petri & von Wangenheim 2017).

The first one is that the assessment or certification of the attained skills based on the game-based learning experience of a player is applied out of the game in most of the prior studies, which may make the assessment of learning effectiveness of the player less detailed than by adopting in-game assessment approaches (Caballero-Hernandez et al. 2017). Therefore, some important pieces of information for assessing how a player utilizes the information feedback offered by the game to resolve the learning problems faced during the game may be missing, making it difficult to comprehend the actual effects of the game. This may, consequently, make the research results suffer from significant validity problems (Petri & von Wangenheim 2017).

Additionally, while prior studies of GBLS address various aspects of modern social and constructivism learning theories, including active, constructive, and playful learning, learning by doing, player motivation and engagement, critical thinking, and problem solving, there is a need to call a shift of future research from unclear/unspoken game design issues to the integrated and vivid investigation of the interactions among presentation logic of in-game content (e.g., in-game information feedbacks), technology-related factor (e.g., technology-acceptance factors), and essential elements of modern learning theories (e.g., learning motivations,

engagement, and effectiveness) in order to advance the current understanding of the design principles of digital games for educational purposes (i.e., serious games) (Kordaki & Gousiou 2017). In other words, this type of research can contribute to our knowledge of game-based learning by explaining in more details of what GBLS features are critical in terms of supporting learning and facilitating individuals' engagement in learning activities (Boyle et al. 2016). Therefore, this study is conducted to further address the two issues summarized above by simultaneously considering the interactions of the factors related to game content (i.e., information feedbacks), technological features (i.e., technology-acceptance factors), and learning-related elements (i.e., learning motivations and learning effectiveness).

2.2 Technology Acceptance Model (TAM)

Technology Acceptance Model was rooted in the Theory of Reason Action. In other words, TAM adapted attitudinal determinants and utilized perceived usefulness and ease of use to replace attitude, while excluding subjective norm (Bagozzi, Davis, & Warshaw 1992; Davis et al. 1989).

Perceived usefulness is defined as the degree to which users the use of the information system (IS) can offer significant help and benefits to its users, such as reduced work hours and increased work performance (Davis et al. 1989). On the other hand, perceived ease of use refers to the degree to which users perceive that the use of the IS is effort free (Davis et al. 1989). Additionally, TAM proposes that external variables may impact perceived usefulness and perceived ease of use. Furthermore, when the degrees of the users' perceived usefulness and ease of use are high, their attitude, behavioral intention and actual behavior regarding using the IS can be enhanced (Shin 2008; Lee, Kozar, & Larsen 2003).

Moreover, TAM proposes that external variables, including operational efficiency, quality of user interface, IS availability, information accuracy, and the support of IS departments can significantly affect on perceived usefulness and ease of use of the users. Different types of IS use have different significant external variables depending on the contexts of IS usage.

TAM has been intensively adopted and studied in various research areas for evaluating the impact of IS on human behaviors and performance. However, TAM is still considered a significant framework for evaluating individuals' acceptance of various information technologies and/or IS. For example, Martin-Garcia, Martinez-Abad, & Reyes-Gonzalez (2019) indicate that TAM is fairly useful in terms of investigating students' acceptance of various complex instructional IS because of its explanatory ability of explaining user behavior at different stages of technology adoption and its scalability in terms of integrating new theoretical perspectives for explaining adoption-related issues. Scherer, Siddiq, & Tondeur (2019) also find it

useful to adopt TAM to explain teachers' adoption of digital technologies for supporting their teaching. Therefore, there have been education-related studies that have adopted TAM the theoretical base for developing various novel theoretical perspective for comprehending the influences of various educational technologies on students' learning effectiveness (e.g., Alismaiel, Cifuentes-Faura, & Al-Rahmi 2022; He et al. 2023; Lefrid et al. 2023; Rukhiran, Wong-In, & Netinant 2023).

2.3 Information Feedback (IF)

Information feedback is offered via the process of the responses of the IS to users based on the identifiable messages acquired from users' interactions with the IS (Shao & Macari 2008). In GBLS contexts, information feedback mechanisms provide GBLS users with information or evaluation, such as answers to questions, assignment grades and comments (Liu et al. 2021; Lin & Wang 2023). Therefore, in this study, information feedback can be viewed as the responses, including systematic evaluation or other forms of information, that the GBLS offers the users to facilitating learning.

Some prior studies (e.g., Gonzalez 2005; Liu et al. 2021; Sengupta & Abdel-Hamid 1993) mention that there are three types of information feedback, which are outcome feedback, feedforward and cognitive feedback. Outcome feedback offers simple outcome after decision making but includes neither predictive nor explanatory information. Feedforward refers to a summary composed of friendly tips, operational guidance, or faulty operation warnings produced by an augmented-reality learning system to help users/learners enhance their learning effectiveness or explore new problem-solving methods (Rodríguez et al. 2022). Cognitive feedback refers to information feedback that may help users/learners to make decisions in terms of which area they have to learn more thoroughly (Sengupta & Te'eni 1993).

2.4 Learning Motivation (LM)

In general, motivation is one of the main drivers of effective learning behaviors (Hsu & Huang 2006). Juriševic et al. (2008) indicate that learning motivation is composed of multiple elements, such as interest, goals, attributes, self-image, and external enticements. Those authors also point out that these elements help develop extrinsic stimulus for learning (e.g., learning for grades, praises, avoiding punishment, and social acceptance and intrinsic stimulus for learning (e.g., learning for mastering and learning for knowledge. Learning motivation is regarded as a conscious striving towards learning progress, the striving for learning, task, or mastery goals. Therefore, learning tasks that include some favorable characteristics from the learners' perspective can make learners have a conscious striving towards learning progress and strive for learning (Dweck & Leggett 1988; Nicholls 1984; Spinath & Spinath 2005).

Prior studies have reported mixed results regarding how the use of GBLS is associated with the learners' motivation, which is critical in terms of enhancing

learners' engagement in the learning processes of GBLS (Liu et al. 2021; Proulx, Romero, & Arnab 2017; Wouters et al. 2013). Therefore, it is important to further investigate this issue. Pintrich et al. (1991) proposed a model of motivated learning strategies for the measurement of learning motivation, which is referred to as the Motivated Strategies for Learning Q questionnaire (MSLQ) scale. The MSLQ covers a motivation section and a learning strategies section, which are measured by indicators that belong to six motivational dimensions. Definitions of those dimensions are presented as follows (Pintrich et al. 1991):

(a) Intrinsic goal orientation: Intrinsic goal orientation concerns the degree to which the students perceive themselves to participate in a task for reasons such as challenge, curiosity, and mastery.

(b). Extrinsic goal orientation: Extrinsic goal orientation concerns the degree to which the students perceive themselves to participate in a course for reasons such as grades, rewards, performance, evaluation by others and competition.

(c). Task value: Task value refers to the student's evaluation of the how interesting, how important, and how useful the task is. In other words, students think about value parts to the course.

(d). Control of learning beliefs: Control of learning refers to students' beliefs that their efforts to learn will produce the positive outcome. In other words, the outcomes are up to one's own effort, in contrast to external factors, such as the teacher.

(e). Self-efficacy for learning: Self-efficacy refers to the students' beliefs that they can learn the skills and use them to accomplish a task.

(f). Test anxiety: Test anxiety refers to worry component and it will disrupt the performance due to the students' negative thoughts before the test or during the test.

This study measures students' learning motivation in the context of GBLS use among students by adopting the MSLQ scale (Pintrich et al. 1991). However, because the use of GBLS used in this study is voluntary, students may not care about the extrinsic motivational factors, such as the poor scores and additional rewards. Therefore, the dimension of extrinsic goal orientation is excluded from the measurement of learning motivation in this study. Additionally, learners' control of learning concerns about their beliefs of whether their own efforts to learn would achieve learning outcome (Prensky 2001), which is irrelevant to the use of GBLS. Therefore, this study excluded this dimension as well. Finally, the test of the GBLS of this study was meant to offer GBLS users with information feedback rather than evaluating their actual learning performance, which is different from the purpose of the tests taken in official educational contexts (Alessi & Trollip 2001). Therefore, students are unlikely to develop test anxiety. Thus, this study also excluded this dimension. To conclude, this study adopted three out of the six dimensions of MSLQ,

which include intrinsic goal orientation, task value, and self-efficacy to measure GBLS users' learning motivation.

2.5 Perceived Learning Effectiveness

Banerjee et al. (1999) indicate that learning effectiveness can be considered the ability of an individual to use the knowledge and skills learned from problem examples and apply them into similar or subsequent problems. Therefore, in this study, perceived learning effectiveness is defined as a learner's perceived quality of the knowledge, skills, and ability learned from the GBLS and his or her perceived personal capability of applying them to other similar problems. The issues related to the evaluation of learners' learning effectiveness have been intensively discussed in the literature and there are a number of frameworks for evaluating learning effectiveness that have been constantly adopted in prior studies (Bromme, Pieschl, & Stahl 2010; Bushnell 1990; Holcomb 1993; Kirkpatrick 1998; Kirkpatrick & Kirkpatrick 2006).

While the criteria for determining how learning effectiveness ought to be evaluated differ across various learning contexts and various professional areas, the Four Level Evaluation (FLE) Model proposed by Kirkpatrick (1998) and Kirkpatrick & Kirkpatrick (2006) has been constantly adopted to evaluate individual learning effectiveness at different levels of educational contexts in the literature. O'Neil et al. (2005) argue that the FLE model is appropriate for evaluating individual learning effectiveness in GBLS-related learning contexts because of its comprehensiveness in terms of encompassing the evaluation of multiple key aspects of learning for various learning purposes. Therefore, in the study the FLE framework is adopted to measure the construct of perceived learning effectiveness of individuals in order to acquire an understanding of the actual effects of technological factors (ease of use and usefulness) and game content factors (information feedbacks) on learners' learning performance.

The FLE framework includes four levels of evaluation of reaction (level one), learning (level two), behavior (level three), and results (level four) (Kirkpatrick 1998; Kirkpatrick & Kirkpatrick 2006). The level of reaction focuses on evaluating how learners react to or are satisfied with the learning activities (e.g., GBLS-supported courses) in order to develop an understanding of the perceptions of learners regarding the course content, teaching method, presentation skills, and so on. The level of learning aims to evaluate whether learners understand and absorb the information delivered via the learning activities by measuring their learning performance via various forms of formal or informal tests (e.g., traditional pencil and pen exams, oral quizzes, or practical field examination) after the completion of the focal learning activities. The level of behavior concentrates on evaluating whether learners have learned from the learning activities and applied what is learned to the actual tasks. This type of evaluation can enable us to understand not only whether the learners can

apply the knowledge and skills learned to the real work but also observe whether the learners change their behavior regarding performing their work in the workplace after taking the focal learning activities. The level of results is related to the overall evaluation of whether the focal learning activities have significantly contributed to the learners' learning performance by improving their performance on completing actual task at workplace.

3. DEVELOPMENT OF THE RESEARCH MODEL

As discussed previously, this study aims to investigate the relationships among information feedback, learning motivation, perceived usefulness, perceived ease of use, and perceived learning effectiveness of students in the context of GBLS use. The research model developed is presented in Figure 1. The development of the research hypotheses are discussed in the subsequent sections.

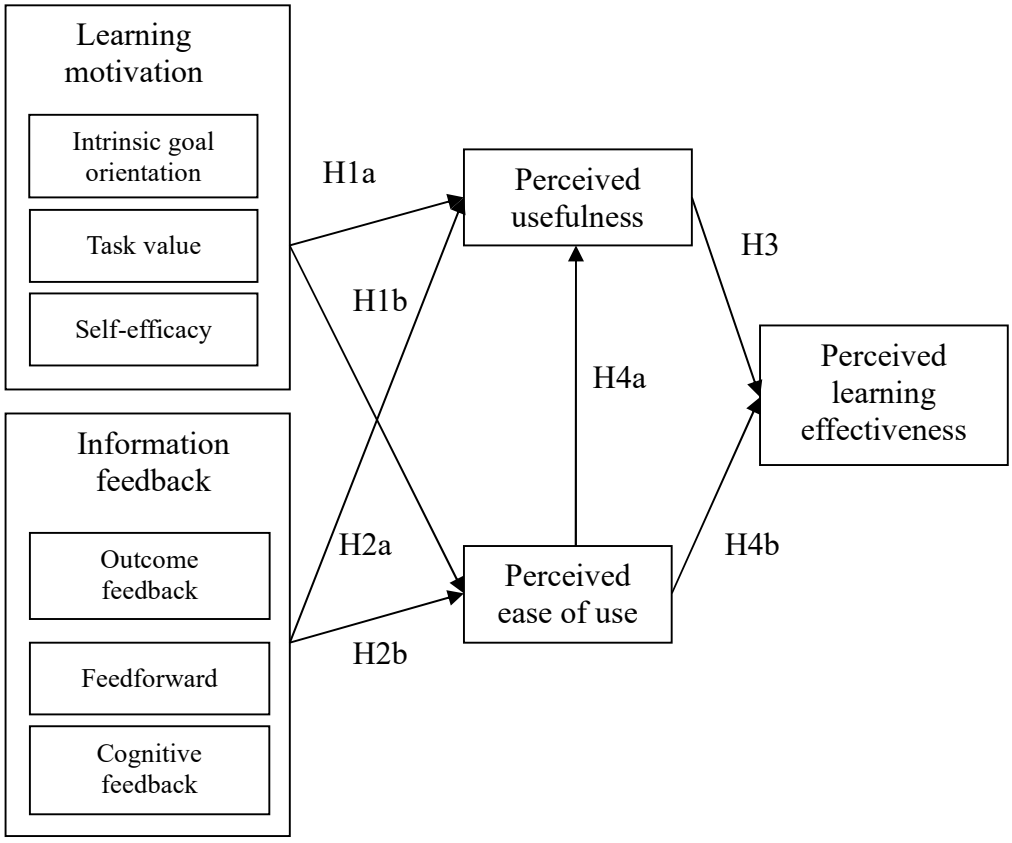

Figure 1: The research model of the use of GBLS

3.1 Learning Motivation and TAM factors

Research indicates that learning motivation will positively impact GBLS users' perceived usefulness and ease of use regarding the use of the GBLS (Huang et al. 2006; Scherer et al. 2019). For example, Venkatesh (2000) argue that when users' level of intrinsic motivation is high, they are likely to find the IS to be interesting, useful, and easy to use. Additionally, some prior studies imply that when IS users

have a high level of motivation, they tend to have a high level of confidence of their own abilities of using the IS, and thus are likely to find the IS to be useful and easy to use (Huang et al. 2006; Ong, Lai, & Wang 2004). Moreover, Alismaiel et al. (2022) imply that a high level of student motivation tends to encourage students to engage in using digital learning tools, and thus the students are likely to perceive the tools to be useful and easy to use as a result of their expectation of achieving desired learning outcome via using the tools. He et al. (2023) also indicate that learners' motivation for acquiring educational resources via IS-based tools (e.g., GBLS) enable them to value the IS-based tools by perceiving the tools to be useful and easy to use if their need for acquiring educational resources is fulfilled. Therefore, we hypothesized:

H1a: Learning motivation has a positive effect on perceived usefulness of GBLS

H1b: Learning motivation has a positive effect on perceived ease of use of GBLS

3.2 Information Feedback and TAM Factors

Chenoweth, Dowling, & Louis (2004) and Nalanagula, Greenstein, & Gramopadhye (2006) point out that it is critical to for an IS to offer of valuable feedforward and cognitive feedback to assist its users in making decisions, which can increase the IS users' perceived usefulness and perceived ease of use. Additionally, Liu et al. (2021) indicate that when the information feedback of the GBLS havs offered critical information for learners to evaluate and/or improve their learning effectiveness, they tend to consider the GBLS to be of high quality. This imply the positive influences of information feedback on learners' perceived usefulness and ease of use regarding the GBLS. Moreover, He et al. (2023) state that perceived information support (i.e., information feedback) offered by the IS for supporting learning help students resolve problems related to the learning processes, which can lead to the increase in the students' perceived usefulness and perceived ease of use of the IS. Therefore, we hypothesized:

H2a: Information feedback has a positive effect on perceived usefulness of GBLS

H2b: Information feedback has a positive effect on perceived ease of use of GBLS

3.3 TAM Factors and Perceived Learning Effectiveness

Research indicates that argue that perceived ease of use can affect perceived usefulness when students learn via using GBLS (Chintalapati & Daruri 2017; Jia & Eder 2009; Venkatesh & Davis 1996). Alismaiel et al. (2022) imply that perceived ease of use tends to come before perceived usefulness rather than being a parallel factor. Therefore, we hypothesized:

H4a: Perceived ease of use has a positive effect on perceived usefulness.

Prior studies imply that if the quality of GBLS is high (in terms of usefulness and ease of use of the GBLS), users' level of learning effectiveness as a result of the

GBLS tend to be high (Ozkan & Koseler 2009; Sun et al. 2008). Dondi & Moretti (2007) also indicate that when the level of GBLS quality (e.g., levels of usefulness of the content offered in GBLS and the ease of use) is high, the GBLS users are more likely to enjoy using it to complete the learning tasks and acquire desirable learning outcome. Tao et al. (2009) also found that perceived usefulness of business simulation games has a significant impact on the learning performance.

Scherer et al. (2019) indicate that the perceived usefulness and ease of use are positively associated with the users' expectation of achieving desired task or learning performance. He et al. (2023) also imply that when the IS for supporting learning has good quality (e.g., useful and easy to use) and is able to offer valuable educational supporting materials, students' learning effectiveness are likely to be enhanced.

H3: Perceived usefulness has a positive effect on perceived learning effectiveness.

H4b: Perceived ease of use has a positive effect on perceived learning effectiveness.

4. RESEARCH METHODOLOGY

4.1 GBLS Design

This study mainly investigates learners' perceived effectiveness when using an online game-based learning system (GBLS). Therefore, we developed a GBLS, which was used to help students learn the concept of normalization of database courses (Figure 2). This GBLS practice integrates with the messages of various types of information feedback to conduct system design. The GBLS used Gadgets drag and drop layout and online tests enabled by iGoogle to allow users to drag and drop appointed pictures in the learning procedures of the GBLS to examine their learning progress and get scores of the in-game tests.

The GBLS includes three main modules, including a normalization information module, audit and rating module, and high-score list module. First, learners browse the interpretation of scripts and rules regarding the game-based learning tasks. Second, the module offers information feedback (i.e., feedforward) to inform learners to complete the learning tasks related to the concept of database normalization of the specific stage, while offering hints regarding how to successfully complete the learning tasks to the learners. Third, formal normalization is categorized into three stages, from the easiest to the hardest to implement the game design challenge. Additionally, during normalization, the module uses JavaScript to make the attribute column of each picture become Gadgets of iGoogle that can be dragged to the appointed form column to implement the control of the progress of GBLS learning

tasks. When learners decide how to arrange the attribute column of each picture, they can start to use the function of the audit and rating module.

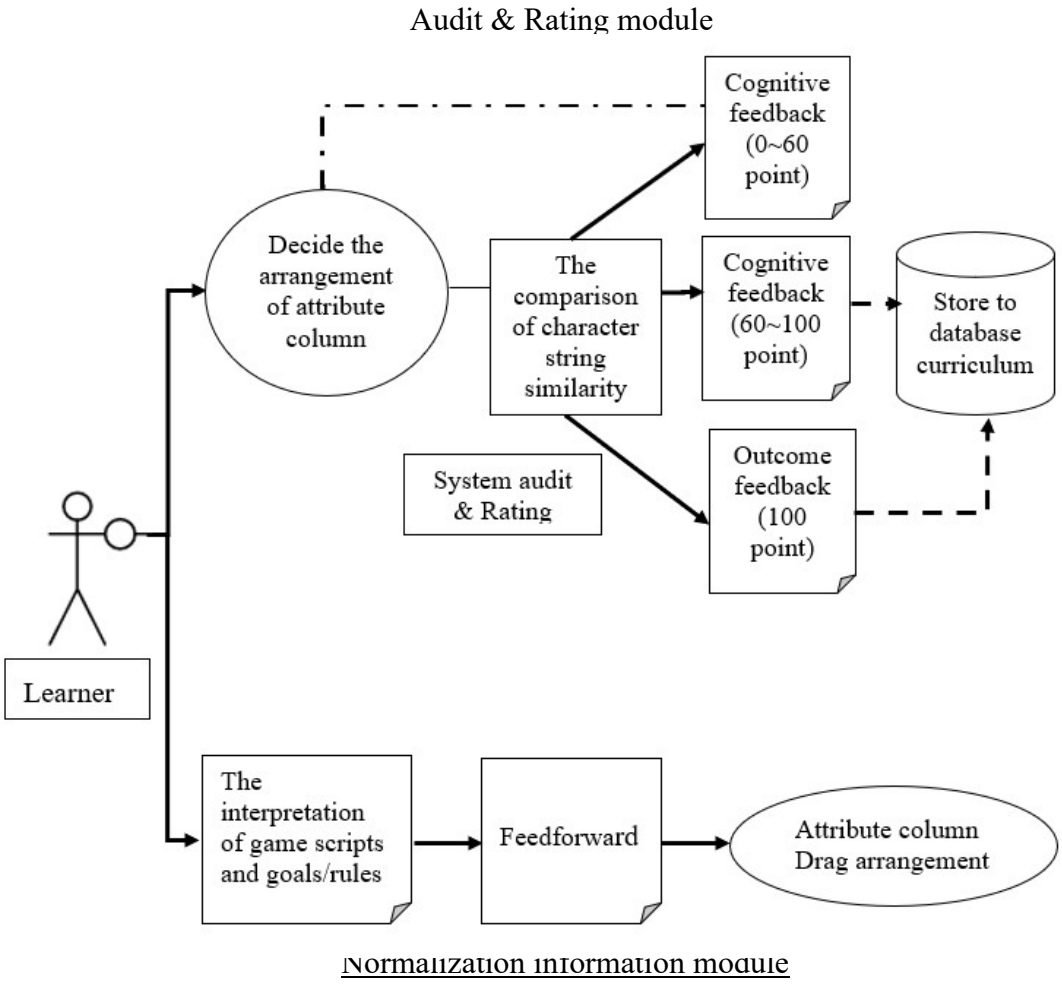

Figure 2: The structure of the GBLS.

The primary processes of using GBLS are presented as follows.

Step 1: Game scripts and the interpretation of goals and rules are presented to inform learners of the learning procedures of the GBLS and learning goals.

Step 2: Feedforward messages are offered before learners begin to perform learning on the concepts of normalization.

Step 3: Learners control the arrangement of dragging the attribute columns, focusing the attribute column of pictures regarding the summary of information form, and dragging the picture by clicking the mouse to make the photograph replicate another new image object.

Step 4: Cognitive feedback and outcome feedback are presented based on the in-game test scores (a total of 100 points) of the learners, which cover scenarios for offering cognitive feedback (0~60 points and 60~100 points) and outcome feedback (100 points). Because cognitive feedback provides a more related message of the task than outcome feedback. Therefore, if the participant scores under sixty, they must return to stage 1 to go through the GBLS learning procedures again. Additionally,

learners with a score ranging from sixty to one hundred are offered not only cognitive feedback related to the concepts of normalization, but also the cognitive feedback that offers the correct arrangement of attribute columns based on the principles of database normalization to make learners understand which parts they have done wrong. Finally, learners who get the score of 100, the GBLS offers them outcome feedback by simply informing them their scores of the in-game tests.

4.2 Research Design

This study used an empirical research design and used a questionnaire to collect survey data. We eventually recruited 322 students who majored in information systems/computer sciences who had not taken database management courses as our research participants from three research-based universities located in Tainan City and Taichung City, Taiwan. The participants were asked to complete the learning tasks of the GBLS that was designed specifically for this study, and then to fill out the questionnaire. To encourage individuals to participate in this study, all the participants were enrolled in a lottery program of the money vouchers of a popular chained convenience stores in Taiwan.

4.3 Research Instruments

In this study, all survey items were adopted from the literature, as indicated in Appendix A, to examine students' learning effectiveness with regard to using GBLS for learning. All items were measuring using a 7-point Likert scale (1 = strongly disagree; 7 = strongly agree). A pilot test was performed by collecting data from 30 qualified respondents. Cronbach's alpha values of the first-order latent constructs in the proposed research model were evaluated to assess the reliability of the survey items used. The initial results had indicated a number of items that had compromised the reliability of their respective constructs, and they were thus removed. The analysis results after the item deletion process revealed that the Cronbach's alpha values of all the first-order constructs were higher than the recommended threshold value of 0.7 (Hair et al., 2019). Thus, all the remaining items were included in the official questionnaire.

4.4 Data Analysis Method

This study developed a research model that includes second-order latent constructs (i.e., learning motivation, information feedback, and perceived learning effectiveness). Therefore, the technique of partial least square structural equation modeling (PLS-SEM) was adopted. We performed the confirmatory factor analysis (CFA) to validate the reliability, convergent validity, and discriminate validity of the measurement model of the proposed research model based on the suggestions of Hair et al. (2019). First, we measured convergent validity using multiple criteria, as follows: (1) the factor loadings are greater than 0.7; (2) the values of average variance

extracted（AVE）are greater than 0.5; and (3) the values of composite reliability (CR) are greater than 0.7. Additionally, discriminant validity was checked using the Fornell & Larcker (1981) criterion. Finally, regarding the validation of the structure model for testing our research hypotheses, bootstrapping technique (5000 times) was used.

5. RESEARCH RESULTS AND DISCUSSION

Regarding the measurement model, this study complied with the CFA principle; thus, each reflective first-order construct for CFA has at least three items. As shown in the Appendix A, all factor loadings ranged from 0.71 to 0.93, which were greater than the threshold value of 0.7. Additionally, Table 1 shows that the Cronbach alpha statistics ranged from 0.74 to 0.94, which were greater than the recommended threshold value of 0.7. Moreover, the AVE values ranged from 0.66 to 0.81, which were greater than the recommended threshold value of 0.5. Finally, the CR values ranged from 0.85 to 0.93, which were greater than the recommended threshold value of 0.7. Therefore, adequate convergent validity is exhibited in the measurement model. Additionally, Table 1 shows that each AVE was higher than the square of correlation coefficients. Thus, the discriminant validity was ensured in the measurement model.

Regarding the structural model, as shown in Table 2, this study adopted information feedback (i.e., feedforward, cognitive, outcome), learning motivation (i.e., intrinsic motivation, self-efficacy, task value), and perceived learning effectiveness (i.e., behavior, learning, response, result) as the formative second-order constructs. Table 2 shows that all VIFs (ranging from 1.73 to 4.45) were smaller than the recommended threshold value of 5, suggesting that multicollinearity is a serious issue in this study. The results reveal that it is adequate to use the structural model to examine the proposed hypotheses. Figure 3 shows that the hypotheses testing results, the standardized path coefficients, and the R squares of the endogenous latent constructs.

Table 1: Discriminant validity and convergent reliability.

Construct	1	2	3	4	5	6	7	8	9	10	11	12
1 Feedforward	**0.67**											
2 Cognitive feedback	0.56	**0.66**										
3 Outcome feedback	0.47	0.46	**0.66**									
4 Intrinsic goal orientation	0.30	0.28	0.35	**0.72**								
5 Self-efficacy	0.22	0.24	0.26	0.31	**0.78**							
6 Task value	0.24	0.23	0.32	0.62	0.42	**0.76**						
7 Perceived ease of use	0.24	0.27	0.30	0.24	0.34	0.28	**0.77**					
8 Perceived usefulness	0.30	0.27	0.40	0.45	0.39	0.59	0.40	**0.77**				
9 Behavior	0.24	0.21	0.31	0.36	0.31	0.45	0.36	0.66	**0.81**			
10 Learning	0.26	0.28	0.31	0.30	0.27	0.34	0.33	0.57	0.65	**0.76**		
11 Response	0.30	0.32	0.51	0.42	0.40	0.45	0.45	0.63	0.56	0.46	**0.70**	
12 Result	0.30	0.27	0.38	0.36	0.30	0.42	0.34	0.61	0.69	0.68	0.56	**0.71**
Cronbach's α	0.75	0.74	0.74	0.80	0.86	0.84	0.94	0.94	0.88	0.84	0.78	0.79
CR value	0.86	0.85	0.85	0.88	0.92	0.91	0.95	0.95	0.93	0.90	0.87	0.88

Note: The values of the AVE statistics were at the diagonal entries, and the values of the squared correlation coefficients were at the non-diagonal entries.

Table 2: The weights and VIF of the formative second-order constructs.

Second-order construct	**First-order construct**	**Weight (*t* value)**	**Standard error**	**VIF**
Information feedback	Feedforward	0.38* (30.16)	<0.001	2.64
	Cognitive	0.36* (29.32)	<0.001	2.58
	Outcome	0.38* (33.97)	<0.001	2.15
Learning motivation	Intrinsic goal orientation	0.35* (65.14)	<0.001	2.68
	Self-efficacy	0.38* (87.02)	<0.001	1.73
	Task value	0.41* (68.82)	<0.001	3.18
Perceived learning performance	Behavior	0.31* (80.41)	<0.001	4.23
	Learning	0.28* (78.36)	<0.001	3.66
	Response	0.24* (82.04)	<0.001	2.59
	Result	0.27* (68.38)	<0.001	4.45

Note: * $p < 0.01$

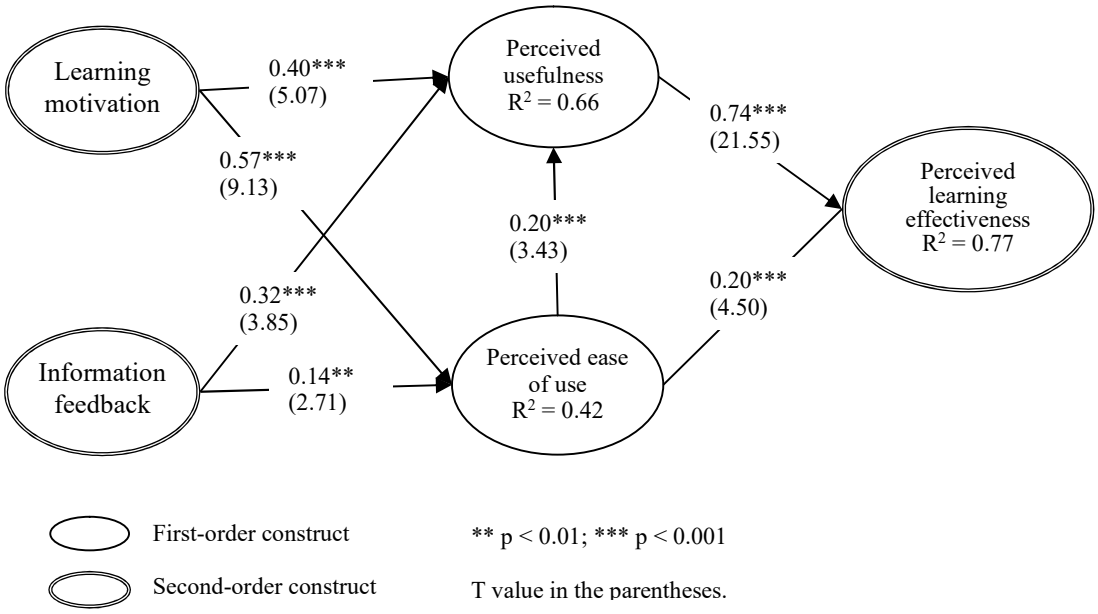

Figure 3: The hypotheses testing results of the GBLS

As shown in Figure 3, the results show that learning motivation and information feedback have a significant positive effect on perceived usefulness (H1a and H2a) and perceived ease of use (H1b and H2b), respectively. Additionally, perceived ease of use has a significant positive effect on perceived usefulness (H4a). Finally, both perceived usefulness and perceived ease of use have a significant positive effect on perceived learning effectiveness (H3 and H4b).

6. DISCUSSION AND CONCLUSION

Learning motivation was found to positively affect perceived usefulness and ease of use (H1a and H1b), which is consistent with previous studies' findings (Huang et al. 2006; Ong et al. 2004; Scherer et al. 2019; Wigfield & Eccles 2000). This means that students have high learning motivation toward GBLS tend to perceive high levels of usefulness and ease of use of the GBLS. Additionally, information feedback has a positive effect on both perceived usefulness and ease of use (H2a and H2b), which is consistent with the findings of previous studies (Alismaiel et al. 2022; Bajaj & Nidumolu 1998; Huang et al. 2006; Ong et al. 2004). We can infer that the GBLS can offer valuable and applicable information feedback so that the students would find the GBLS to be useful and easy to use.

Furthermore, perceived usefulness has a positive effect on perceived learning effectiveness (H3), which aligns with the findings of previous studies (Scherer et al. 2019; Teo & Noyes 2008). This means that when students perceive their adoption of the GBLS to be useful, they tend to perceive that they have done a fine job in learning the focal learning subjects. Finally, the results show that perceived ease of use positively affects perceived usefulness and perceived learning effectiveness, respectively (H4a and H4b). The findings are consistent with those of some previous studies (Chiu & Wang 2008; Ozkan & Koseler 2009; Scherer et al. 2019; Sun et al. 2008). This means that when students think it is useful to use the GBLS to achieve their learning goals, they would perceive the GBLS to be easy to use because they can acquire valuable learning materials and/or information via the GBLS in a rather convenient way. Those findings also indicate that if teachers want to enhance the students' perceived learning effectiveness; the design of the GBLS need to meet the students' expectation of ease of use in order to encourage them to continue to take advantage of the GBLS to learn effectively.

6.1 Implication for Theory

Our results offer some theoretical implications. First, with reference to the perspective of information feedback and TAM model, there is a need for more studies to investigate the relationships among information feedback, learning motivation, perceived usefulness, and perceived ease to use in the context in which GBLS is used to support student learning. While previous studies focus only on adopting the TAM (Davis et al. 1989) to investigate learning motivation in various e-learning contexts (e.g., Alismaiel et al. 2022; He et al. 2023; Lefrid et al. 2023; Martin-Garcia et al. 2019; Rukhiran et al. 2023), very few of them have simultaneously consider the interaction between information feedback and TAM factors on students' learning effectiveness in GBLS contexts. Therefore, the findings of this study contribute to the

literature of GBLS by validating the relationships among information feedback, perceived usefulness, perceived ease of use, and perceived learning effectiveness in GBLS contexts.

Additionally, from the perspective of learning motivation, prior studies focus on investigating the effects of various types of learning motivation on students' learning effectiveness in various educational contexts in which GBLS is adopted (e.g., Liu et al. 2021; Proulx et al. 2017; Wouters et al. 2013). However, studies that specifically investigate how learning motivation indirectly affects students' learning effectiveness via TAM factors (e.g., perceived usefulness and perceived ease of use) are rare. Therefore, this study has focused on this under-addressed research direction and respond to the call for studies of how TAM factors may impact students perceived learning effectiveness (Wang & Lin 2021).

Finally, the findings contribute to the literature by validating the causal relationships among information feedback, learning motivation, TAM factors, and perceived learning effectiveness, which, to the best of our knowledge, has not been done in the GBLS literature. Therefore, the multi-layer causal relationships that are validated by this study may serve as useful references for future researchers to develop novel theoretical viewpoints that can advance our understanding of the design and implementation of GBLS to facilitating learning in various educational contexts.

6.2 Implication for Practice

First, the results of this study can be used as guidelines for teachers to consider how to design a high-quality GBLS to support their teaching efforts and enhance students' perceived learning effectiveness. To elaborate on this, information feedback and learning motivation are all significant determinants of perceived usefulness and perceived ease to use. Information feedback is a crucial indicator of the quality of GBLS, which can positively impact the effectiveness of students' decision-making by offering them with useful and timely information in GBLS learning processes (Dondi & Moretti 2007; Pivec & Kearney 2007). Therefore, while we design GBLS, we must consider how the design of GBLS can enhance students' learning motivation and what information feedback that GBLS should offer and at what moments in order to increase the level of students' perceived ease of use and usefulness regarding their use of the GBLS, which subsequently contribute to the increase in the level of students' perceived learning effectiveness.

For example, instructors can enhance students' learning motivation by offering mechanisms such as adequate challenges regarding the learning subjects and supplementary materials (e.g., video clips or real-world cases) that can arouse the intertest of the students in the focal learning tasks. Those efforts may lead to a favorable perception of the students regarding their use of the GBLS and encourage to

engage in the learning processes supported by the GBLS, and eventually enhance their learning effectiveness. Additionally, GBLS should be equipped with friendly user interfaces and intuitive usage principles that are consistent with the use patterns of popular digitalized services. This would make the GBLS easy to use because the users do not have to spend too much time to learn how to use it. Therefore, they will perceive a good GBLS quality and are more willing to continue to use the GBLS to increase their learning effectiveness.

6.3 Limitations and Future Research Directions

This study has some limitations, as follows. First, game-based learning of the experiment only focuses on the information-management related courses, and therefore the research participants were limited to the college students who majored in information systems/computer sciences. The results of this study, thus, might not be applicable to other educational contexts related to other academic disciplines in which GBLS is applied. Future research can consider using the research model of this study or its extension to investigate the use of GBLS in other educational contexts.

Second, while this study is among the first group of studies that investigate the relationship between information feedback, learning motivation, TAM factors, and perceived learning effectiveness of students in the GBLS contexts, this study did not exhaust all the factors that are relevant to the constructs of interest of the proposed research model. Therefore, there are a few worth noting future research directions in this regard. For example, research implies the importance of investigating the relationship between learning style, learners' inherent interest in the learning subjects, information feedback, flow experience, and cognitive loads (e.g., Cheng et al. 2022; Liao et al. 2019; Wang et al. 2023), while they have not considered the relationships among those factors with perceived usefulness and perceived ease of use proposed by the TAM. Future research efforts may focus on addressing this particular issue. Additionally, while this study investigates the effect of learning motivation on TAM-related factors and students' learning effectiveness in GBLS contexts, there are studies that identify different forms of learning motivation that are worth further investigation, including autonomous motivation (Liu et al. 2021), intrinsic/extrinsic motivation (Liao et al. 2019), and motivational drivers (e.g., challenge, curiosity, and fantasy) (Park et al. 2019_a). Future research may focus on investigating the relationships among information feedback, various forms of learning motivations on perceived usefulness, perceived ease of use, and perceive learning effectiveness in GBLS contexts.

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Appendix A. Survey instruments

Construct	Items	Factor loading
Learning motivation (Huang et al. 2006; Pintrich et al. 1991)	*Intrinsic goal orientation*	
	(1) The GBLS challenges me so I can learn new things.	0.87
	(2) The GBLS arouses my curiosity, even if the learning subject is difficult to learn.	0.79
	(3) The GBLS course makes me try to understand the learning content as thoroughly as possible.	0.88
	Task value	
	(1) I am very interested in the content area of the learning subject of the GBLS.	0.84
	(2) I think the learning materials in the GBLS is useful for me to learn.	0.90
	(3) Understanding the subject matter of the learning content of the GBLS is very important to me.	0.88
	*Self-efficac*y	
	(1) I am confident I can do an excellent job on the tests of the GBLS.	0.88
	(2) I am confident I can understand the materials taught in the GBLS.	0.91
	(3) Considering the difficulty of the learning subject of the GBLS, I think I will do well in the GBLS.	0.86
Information feedback (Liu et al. 2021)	*Feedforward: Before the GBLS test, ……*	
	(1) information that is related to the subject of normalization provided by the GBLS is helpful.	0.84
	(2) instructions of normalization provided by the GBLS help me develop a basic understanding of the subject of normalization.	0.85
	(3) information that is related to the subject of normalization. provided by the GBLS makes me aware of which parts of the subject of normalization of which I should improve my understanding.	0.75
	Cognitive feedback	
	(1) I read the feedback of the GBLS in detail.	0.86
	(2) I am not interested in the feedback offered by the GBLS. *(reverse coded)*	0.79
	(3) The feedback of the GBLS is very helpful.	0.8
	Outcome feedback	
	(1) The feedback provided by the GBLS based on my test results do not make me better understand the subject of normalization. *(reverse coded)*	0.71
	(2) The feedback provided by the GBLS based on my test results makes me better comprehend the subject of normalization.	0.73

	(3) The feedback provided by the GBLS based on my test results makes me aware of which parts of the subject of normalization of which I should improve my understanding.	0.71
Perceived usefulness (Davis et al. 1989; Wang & Lin 2021)	(1) Using GBLS would improve my performance.	0.88
	(2) Using D GBLS would enhance learning outcome.	0.87
	(3) Using GBLS would enhance learning quality.	0.90
	(4) Using GBLS would enable me to learn effectively.	0.91
	(5) Using GBLS can save time.	0.90
	(6) Using GBLS is useful for future work.	0.80
Perceived ease of use (Davis et al. 1989; Wang & Lin 2021)	(1) Learning to use GBLS was easy for me.	0.89
	(2) Learning GBLS takes less time.	0.89
	(3) I found it was easy to use GBLS to do what I want it to do.	0.91
	(4) It would be easy to become skillful at using GBLS.	0.90
	(5) I found GBLS easy to use.	0.85
	(6) I found it took less time to deal with the problem during using GBLS.	0.83
Perceived learning effectiveness (Chrysafiadi & Virvou 2013; Huang et al. 2015)	*Behavior*	
	(1) The GBLS positively affects my perception about database normalization.	0.93
	(2) The GBLS draws my interest in database normalization.	0.92
	(3) The GBLS motivates me to be involved in the learning of database normalization.	0.84
	Learning	
	(1) I think the GBLS makes database normalization more interesting.	0.75
	(2) I think the GBLS is worth trying.	0.92
	(3) I think everyone can complete his or her own tasks on the GBLS if he or she studies hard.	0.93
	Reaction	
	(1) The GBLS helps me understand the logic of database normalization.	0.90
	(2) I think the GBLS is useful as an educational tool.	0.90
	(3) I understand the concept of database normalization after using the GBLS.	0.70
	Result	
	(1) The GBLS helps me learn other database-related courses.	0.88
	(2) The GBLS helps me in my studies.	0.91
	(3) The GBLS helps me understand better other lessons of database management.	0.72