

Developing Computer Science Learning System with Hybrid Instructional Method*

YU-HSIN HUNG, RAY-I CHANG and CHUN-FU LIN

Department of Engineering Science and Ocean Engineering, National Taiwan University, 1 Roosevelt Rd, Sec. 4, Taipei, Taiwan.

E-mail: Lccf73211@gmail.com

Technology has flourished, and diverse teaching techniques have emerged such as eBooks, massive open online courses, and gamification. Accordingly, technologies continue to provide a revolutionary improvement on traditional learning environments. The pedagogic trend is becoming “student-centered”. Problem-based learning (PBL) is the use of problems to motivate learners to apply research concepts and thinking strategies. Gamification provides the learners to actively learn through gamified mechanisms. This study focuses on PBL and gamification to enhance students’ engagement in learning computer science. We developed a computer science learning system (CSLS) comprising three subjects: database management, programming, and data structure. Each subject has problem-solving mini games for students to accomplish tasks using relevant concepts. Results reveal that learners have a 95% probability of obtaining above-average user satisfaction, which suggests that the CSLS can be a good vehicle for cultivating the relevant computer science concepts. Participants’ technology acceptance and their cognitive load when using the system are also determined in the experiment, with the aim of examining learners’ perception while using the CSLS. Further, gamification has indicated a positive effect on students’ learning performance and cognition for learning computer science.

Keywords: gamification; problem-based learning; programming learning; computer science education

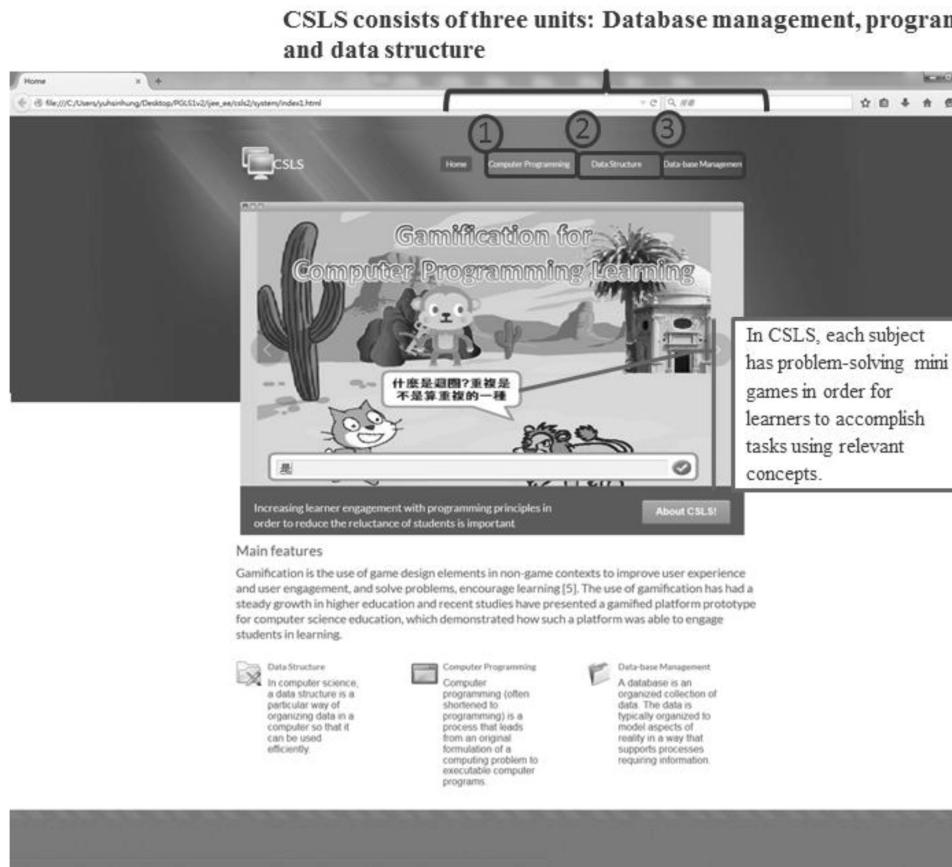
1. Introduction

Programming, data structure, and database management are the fundamental courses in most engineering colleges. Engineering students require a good fundamental knowledge of computer science, and engaging students in this topic is elemental to enhance their learning. Gamification is a pedagogical innovation of incorporating game elements into non-gaming content to maximize user experience and engagement with the topic [1]. Education researchers have demonstrated the value and impact of gamification for engaging students in learning activities [2, 3]. Problem-based learning (PBL) is a student-centered pedagogy wherein students learn through the facilitated experience of problem solving [4, 5]. This study aims to engage students and alleviate their cognition load while learning computer science. Therefore, we developed a gamified computer science learning system (CSLS) that has a series of problem solving games. The study addresses the following research questions:

1. What are students’ perceptions toward the gamified instruction when they are learning computer science concepts?
2. What is the students’ cognition load toward the gamified instruction when they are learning computer science concepts?
3. Is the performance of the gamified instruction effective for students’ computer science learning?

2. Related work

Gamification is considered an educational innovation trend in higher education [6]. Recently, the gamification of learning has attracted considerable attention from researchers, and some have claimed that it has a positive effect on learning emotion [7]. De-Marcos et al. (2014) indicated that games present apparent objectives, which are divided into short-term achievable goals that give a seamless sense of progression to players by providing frequent rewards acting as external motivators [8]. Rapp reported that gamification efforts could identify elements of deeper engagement [9]. Students’ engagement in learning activities plays an important role in education, and according to some researchers, it is the core value of teaching [10]. Ibanez et al. (2010) investigated the efficiency of applying game elements in programming contexts [11], and results indicated that gamification can successfully engage most students in learning programming language. Gamification has the following characteristics [12]: (1) the affordances implemented in gamification have to be similar to the ones used in games, regardless of the outcomes [1]; (2) the role of gamification in invoking similar psychological experiences as games [13]; and (3) conceptualizing gamification is related to the motivational affordances, psychological outcome, and behavior outcome [13]. Gamification in educational environments demonstrated educational success [8, 11]. Alternatively, problem-based learning



(PBL) is a student-centered pedagogy wherein students learn through facilitated experience of problem solving [4, 5]. For engineering education, PBL offers good educational prospects, and it has been implemented as a partial strategy for learning specified knowledge such as engineering [4]. Therefore, gamification and PBL were employed to develop the CSLS.

3. Methodology

Database management, programming, and data structure are three units of the CSLS; each has a mini problem-solving game (see Fig. 1). Game scenarios, game thinking, and game mechanics were employed to describe computer science knowledge. Popular topics, such as the treasure hunter, were included in the game scenarios to make it interesting. All the games incorporated tasks that motivated students to apply their knowledge and thinking strategies in solving problems, giving them a deeper conceptual understanding. Figs. 2–4 demonstrate the CSLS gamification.

(1) Unit 1—“The hungry bear”

A database, stored in various types, is considered a

storage value for data manipulation. In the “The hungry bear” unit, we used farm as the game scenario. The barn is the main character, and the cabinets in the barn represent the database, which consists of a data table. This scenario demonstrates that data are catalogs and stored in unique columns in the data table, just as the honeypot and farm tool need to be placed on the cabinets. The scenario aims to teach learners the basic data process and how to use structured query language (SQL) in processing data. In the game task, learners are asked to assist the starving bear to procure the honeypot from the food in the cabinets using the SQL description (see Fig. 2).

(2) Unit 2—“Treasure hunter”

Programming can assist a task by building the declared function. The scenario of the “Treasure hunter” is a fox’s treasure hunt. Programming can build the declared function to process a task, and a recursive mechanism can be used to handle repetitive tasks. Exploring the treasure represents the program task, while the key that opens the treasure house door represents the declared function to accomplish the task. In this game, learners obtained clues by solving the programming concept problem.



Fig. 2. The gamification instance in database management.



Fig. 3. The gamification instance programming.

By solving the game task, they can be inspired to understand the meaning of the function in the programming statement (see Fig. 3).

(3) Unit 3—“Happy Zoo”

Data structure is a particular way of organizing data in a computer for efficient usage; data ordering and searching are essential in the performance of programming. Useful systems with good data structures can enhance applications and services. Therefore, designing adaptive, easy-to-understand data structure concepts is important as this study proposes. The “Happy Zoo” unit concerns how to

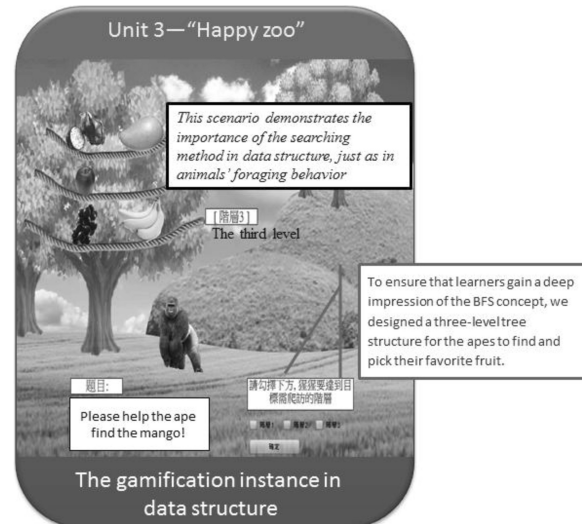


Fig. 4. The gamification instance in data structure.

process data in a search method. Animal foraging behavior and habitual behavior were applied to demonstrate the importance of the searching method in data structure. This scenario was used to search for concepts. Learners were assigned a game task wherein they were required to assist animals to find food (see Fig. 4).

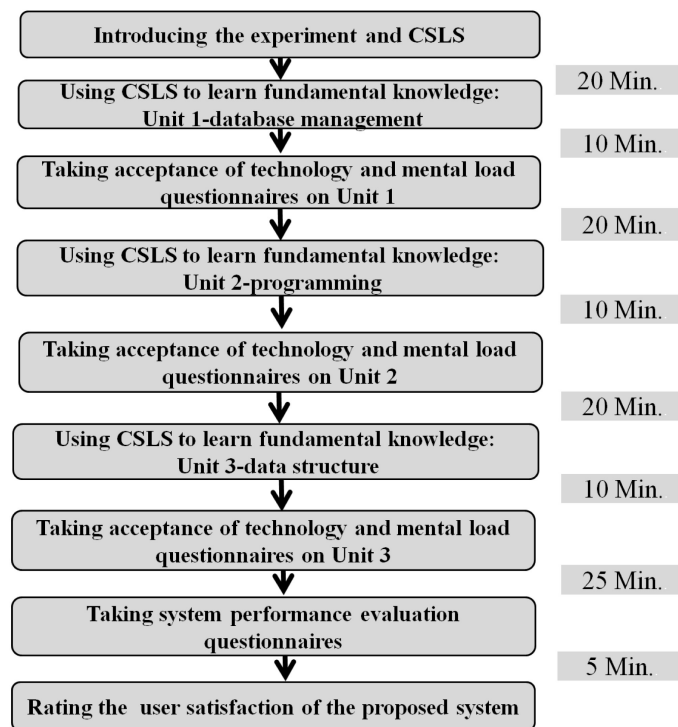
4. Experiment

4.1 Participants and the experiment procedure

This study comprised two experiments: (a) a system performance evaluation and (b) a measurement of students' learning achievement. The collected information is shown in Table 1. The first experiment is investigating the performance of gamified instruction and how it affects learners' technology acceptance and cognition load. Forty-six undergraduate students (male: 26; female: 20) participated in an experiment that lasted 120 minutes. Participants' cognitive load and technology acceptance related to the proposed gamified system were examined. The successful information systems evaluating theory [14] was used to evaluate the system performance. Fig. 5 illustrates the experimental procedure. All participants were assigned the same game scenarios and problem-solving tasks. They received instructions on the experiment and CSLS before starting the activities. The CSLS activities comprised three units: database management, programming, and data structure. In each unit, participants were instructed to use the CSLS to learn fundamental knowledge. After completing the game-based activity, they were instructed to complete the technology acceptance and mental effort questionnaires. Finally, participants were asked to answer the

Table 1. Study parameters using the CSLS

Variables	Description	Type
ID	Identify sample (N = 46)	Numerical
Gender	1 = Male 0 = Female	Categorical
Technology acceptance	Technology acceptance consisted of “perceived ease of use” and “perceived usefulness” evaluation. A total of 13 items in this questionnaire [16], each item determined by a 5-point Likert scale.	Categorical
Cognitive load	A total of 8 items in this questionnaire [26], each item determined by a 5-point Likert scale.	Categorical
System performance evaluation	DeLone & McLean’s IS success model has six dimensions: service quality, system quality, user satisfaction, system use, net benefits, and information quality. Each dimension is rated from 1 to 5.	Categorical
Game scenario	1 = Database management unit. 2 = Programming unit. 3 = Data structure unit.	Categorical
Learning performance	It was composed of 9 items with a full score of 100.	Numerical
Group	2 = Static instruction (N = 49). 1 = Gamified instruction (N = 49).	Categorical

**Fig. 5.** Procedure of the system performance evaluation.

system performance evaluation questionnaire to measure the system performance.

The second experiment compared the students’ learning performance that has used gamified instruction (experimental group) against others who have used the static instruction (control group) to demonstrate if its use affects learning outcomes. The participants were randomly classified into two groups, with one assigned the static instruction and

the other the CSLS. Both of the instructions were based on the same content. In total, 98 university students voluntarily participated in the study with each group comprising 49 participants (see Fig. 6). In the control group, the participants were guided by textual and pictorial descriptions to complete the learning activity, whereas the participants in the experiment group were guided by animation-based game interaction (see Fig. 7).

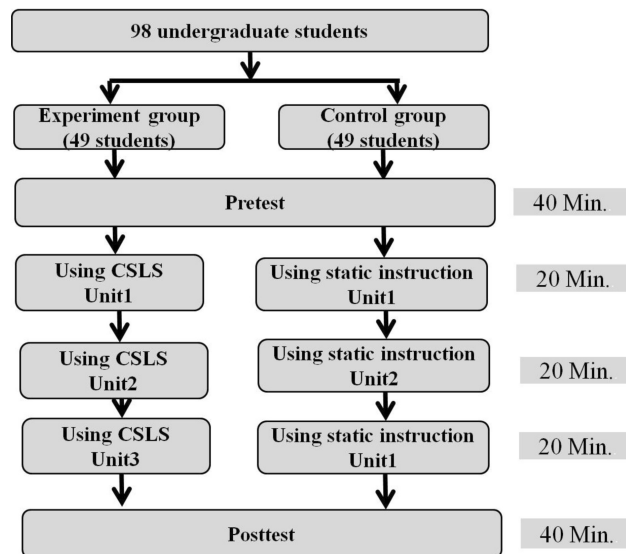


Fig. 6. The procedure for students' learning achievement measurement.

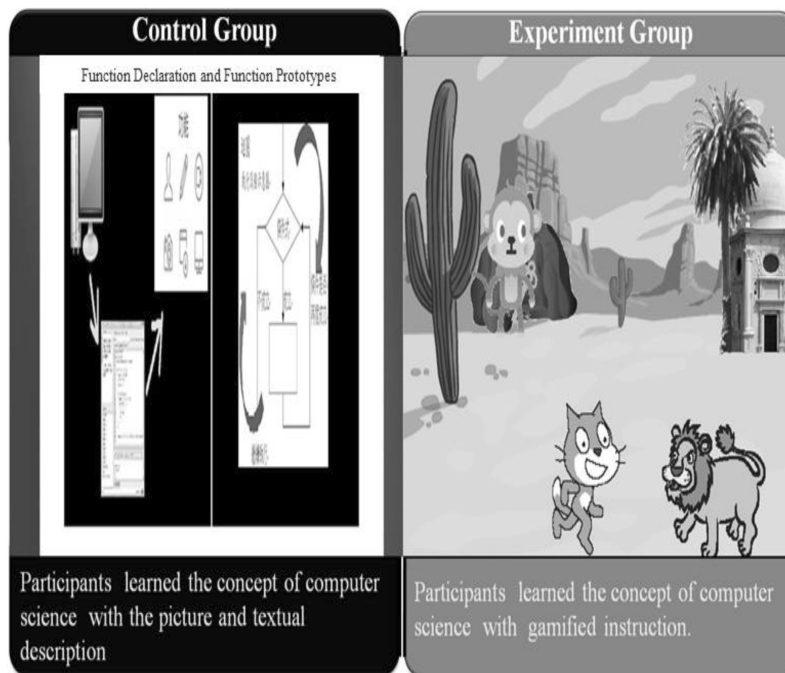


Fig. 7. Different learning materials used in each group.

4.2 Measuring tools

Park (2009) reported that users' intention to use technology is concerned with self-efficacy and technological complexity [15]. The technology acceptance model comprises perceived usefulness and perceived ease of use that affect individuals' beliefs, behaviors, and attitudes toward a software tool. Davis (1989) claimed that perceived ease of use is concerned with the belief that using the technology will be effortless, and perceived usefulness implies that the user believes the technology will improve his/her performance. The technology acceptance

model is widely applied in digital learning [16–23], and previous research revealed that learners' perceived usefulness and ease of use are critical factors affecting learners' perceived satisfaction [24]. Students' perception toward the learning tool is related to their learning performance [16], satisfaction, attitude, [15] and learning experiences [25]. Yi and Hwang, (2003) indicated that the critical factors related to user acceptance of technology is an important issue [17].

Accordingly, technology acceptance and cognitive load are also essential measurement factors in

this study. The perception and attitude questionnaire is concerned with learners' perceptions in digital resources, and was developed by Chu et al. (2010) with a reliability coefficient of 0.91. The present study used this questionnaire to determine learners' perceptions about the CSLS after participating in the experiment. The questionnaire measures learners' perceptions in two dimensions: "perceived usefulness" and "perceived ease of use." The questionnaire comprised 13 items to evaluate learners' perceptions: "I think the proposed system can enrich the content of a learning activity" (Q1); "I think using the proposed system is helpful for me to learn the new knowledge (Q2); "The guidance provided by the proposed system can assist the procedure of learning more smoothly" (Q3); "The proposed system can assist me in obtaining useful information" (Q4); "I had better learning performance using the proposed system" (Q5); "Compared with the experience of using other materials, I think the proposed system is more efficient" (Q6); "It is not difficult for me to use the proposed system" (Q7); "The procedure of using the proposed system doesn't need much time" (Q8); "The guidance provided by the proposed system is easy to understand and follow" (Q9); "The objective of the proposed system is to aid me better understand how to identify and classify the features of the target learning objects" (Q10); "I required a brief time to completely understand how to use the proposed system after participating in this learning activity" (Q11); "After participating in the learning activity, using the proposed system is not difficult for me" (Q12); and "Overall, the proposed system is easy to use" (Q13). The first six items were used to measure the "perceived usefulness" and the last seven to measure the "perceived ease of use."

The cognitive load questionnaire was modified by Sung et al. (2013) [26] on the basis of the cognitive load measures proposed by Paas et al. (1992) [27] and Sweller et al. (1998) [28]. The cognitive load questionnaire concerned students' perspective regarding emotional cognition in the learning activity. This study used the cognitive load questionnaire as a research tool to measure learners' mental load when using the proposed system. The cognitive load questionnaire consisted of 8 items: "The content of the learning activity is difficult for me" (Q1); "I spend much effort to answer the questions of the learning activity (Q2); "Answering the question in the learning activity is tiring (Q3); "Answering the question in the learning activity is frustrating" (Q4); "I didn't have enough time to answer the questions of the learning activity" (Q5); "The explanations in the learning activity cause stress for me" (Q6); "To accomplish the learning activity, it took much effort for me" (Q7); and "The explanation of the learning

activity is hard for me to understand" (Q8). The first five items were used to measure the mental load and the last three to measure the mental effort.

Furthermore, the CSLS performance evaluation, on the basis of DeLone & McLean's IS success model [14], included the following six dimensions: information quality, system quality, service quality, system use, user satisfaction, and net benefits. Participants were instructed to rate each dimension of the proposed system. The model includes a specific evaluation factor ranging from "development" to "improvement;" thus, the evaluation dimension consists of user enjoyment, and utilization of quality to service and system performance [29].

5. Results

5.1 Technology acceptance toward using the gamified instruction in computer science learning activities

The instructional design is related to learners' technology acceptance. In this study, participants' technology acceptance was measured after they finished the learning activities. Technology acceptance is separately discussed with "perceived usefulness" and "perceived ease of use." We examined the significance of each item. Response options ranged from "strongly disagree" (1 point) to "strongly agree" (5 points).

(1) Database management

Software was applied to teach database management [30]; digital learning instruction is essential for learning database knowledge. Students' perception toward technology may affect their learning achievement. Compared with programming and data structure learning activities, the "perceived ease of use" obtained a higher evaluation from participants. The complex concept of database management illustrated with gamified material may allow students to perceive that the learning material is easy to use. The results (see Table 2) indicate that t-values were significant in Q1–13 ($p < 0.05$). The t-test results demonstrate that there were significant high scores in "perceived usefulness" (Mean = 4.01) and "perceived ease of use" (Mean = 4.38). In the database management learning activity, participants have a high evaluation, particularly for the proposed system use and its ease. From the "ease of use" perspective, the technology acceptance of database management unit is higher than that of the other two units.

(2) Programming

Table 3 shows that the t-values were significant for Q1–13 of this unit. In terms of technology accep-

Table 2. Results of technology acceptance in database management

Technology acceptance	N	Mean	SD	t-value	Sig.
“Perceived usefulness”	46				
Q1		3.93	0.68	9.32	0.000
Q2		4.09	0.72	10.17	0.000
Q3		4.15	0.87	9.00	0.000
Q4		3.89	0.90	6.72	0.000
Q5		4.02	0.86	8.09	0.000
Q6		3.98	0.83	8.00	0.000
“Perceived ease of use”					
Q7		4.39	0.74	12.67	0.000
Q8		4.33	0.70	12.83	0.000
Q9		4.17	0.74	10.77	0.000
Q10		4.33	0.63	14.18	0.000
Q11		4.41	0.65	14.69	0.000
Q12		4.50	0.59	17.33	0.000
Q13		4.52	0.55	18.86	0.000

$p < 0.05$.

tance, the mean values were 3.86 for “perceived usefulness” and 3.76 for “perceived ease of use.” The results demonstrate participants’ confidence that the guidance provided by the proposed system was an efficient learning procedure (3.89; Q3) and was easily understood in learning programming (3.87; Q10). Programming education received considerable attention, especially the use of learning instructions. Participants’ perception toward using instruction may influence their learning achievement.

(3) Data structure

Table 4 results indicate that each item of this unit obtained a high technology acceptance ($p < 0.05$). The t-test results show that there were significant

high scores in “perceived usefulness” (Mean = 4.07) and “perceived ease of use” (Mean = 4.24). From the “useful” perspective, the technology acceptance of data structure learning is higher than that of the other two units. Illustrating data structure concepts using gamified material helps students understand the concepts more efficiently.

To summarize, participants had a 95% probability of obtaining above-average technology acceptance using the CSLS. The use of gamification can improve user experience and user engagement [31]; thus, gamification has a positive effect on technology acceptance in the learning activity. Papastergiou’s [32] finding showed that the gaming approach was more effective and motivational for promoting students’ knowledge of computer memory concepts

Table 3. Results of technology acceptance in programming learning

Technology acceptance	N	Mean	SD	t-value	Sig.
“Perceived usefulness”	46				
Q1		3.91	0.78	7.90	0.000
Q2		3.91	0.86	7.16	0.000
Q3		3.89	0.95	6.38	0.000
Q4		3.76	0.74	7.01	0.000
Q5		3.85	1.01	5.69	0.000
Q6		3.83	0.88	6.39	0.000
“Perceived ease of use.”					
Q7		3.76	0.97	5.32	0.000
Q8		3.67	1.03	4.42	0.000
Q9		3.67	1.12	4.09	0.000
Q10		3.87	0.96	6.16	0.000
Q11		3.83	1.00	5.63	0.000
Q12		3.72	1.07	4.56	0.000
Q13		3.78	0.96	5.51	0.000

$p < 0.05$.

Table 4. Results of technology acceptance in data structure learning

Technology acceptance	N	Mean	SD	t-value	Sig.
"Perceived usefulness"	46				
Q1		4.04	0.82	8.68	0.000
Q2		4.04	0.92	7.71	0.000
Q3		4.20	0.86	9.44	0.000
Q4		3.98	0.83	8.00	0.000
Q5		4.13	0.88	8.67	0.000
Q6		4.04	0.89	7.92	0.000
"Perceived ease of use"					
Q7		4.30	0.73	12.18	0.000
Q8		4.20	0.81	10.06	0.000
Q9		4.20	0.69	11.80	0.000
Q10		4.24	0.77	10.98	0.000
Q11		4.20	0.81	10.06	0.000
Q12		4.22	0.70	11.86	0.000
Q13		4.30	0.79	11.27	0.000

$p < 0.05$.

than the non-gaming approach. Liu et al. (2010) demonstrated that perceived ease of use had a significant influence on the intention to use the system [33]. Some studies indicated that the higher learners' perceived usefulness and ease of use led to a more positive effect on learning attitudes, learning experiences, and satisfaction [25]. In this study, the CSLS has good technology acceptance by the users (means = 4.04).

5.2 Cognitive load when using the gamified instruction in computer science learning activities

The instructional design is related to learners' cognitive load. Participants' cognitive load was measured after completing the learning activities. Cognitive load is discussed separately with mental load and effort. We examined the significance of each item. Response options ranged from "strongly disagree" (1 point) to "strongly agree" (5 points).

(1) Database management

Students' cognition load when using the gamified

instruction was significantly low. Lower scores were found in mental load for Q1 ($t = -7.33$), Q2 ($t = -8.01$), Q3 ($t = -8.28$), Q4 ($t = -9.89$), and Q5 ($t = -8.78$) and mental effort for Q6 ($t = -8.51$), Q7 ($t = -7.40$), and Q8 ($t = -9.73$). The results indicated that the participants had a 95% probability of experiencing low mental effort in gamified database management learning (see Table 5). In the database management learning activity, participants perceived answering in the learning activity as less frustrating.

(2) Programming

Cognitive load may be an influential factor in learning programming [34]. Table 6 demonstrates students' cognition load when using the gamified instruction. Lower scores were found in mental load for Q1 ($t = -5.62$), Q2 ($t = -7.57$), Q3 ($t = -5.05$), Q4 ($t = -7.73$), and Q5 ($t = -6.67$) and mental effort for Q6 ($t = -7.10$), Q7 ($t = -4.60$), and Q8 ($t = -7.07$). In the programming unit, participants' cognition load was quite below the average scale. These results are

Table 5. Results of cognitive load on the database management unit

Cognitive load	N	Mean	SD	t-value	Sig.
Mental load	46				
Q1		1.87	1.05	-7.33	0.000
Q2		1.87	0.96	-8.01	0.000
Q3		1.76	1.02	-8.28	0.000
Q4		1.65	0.92	-9.89	0.000
Q5		1.78	0.94	-8.78	0.000
Mental effort					
Q6		1.85	0.92	-8.51	0.000
Q7		1.89	1.02	-7.40	0.000
Q8		1.80	0.83	-9.73	0.000

$p < 0.05$.

Table 6. Results of cognitive load on the programming unit

Cognitive load	N	Mean	SD	t-value	Sig.
Mental Load	46				
Q1		2.04	1.15	-5.62	0.000
Q2		1.89	0.99	-7.57	0.000
Q3		2.11	1.20	-5.05	0.000
Q4		1.85	1.01	-7.73	0.000
Q5		1.93	1.08	-6.67	0.000
Mental effort					
Q6		1.89	1.06	-7.10	0.000
Q7		2.22	1.15	-4.60	0.000
Q8		2.04	0.92	-7.07	0.000

$p < 0.05$.

similar to those of the database management unit, and most participants in the programming activity also perceived that answering the question in the learning activity was less frustrating for them. Programming anxiety, such as a mistaken assessment of their ability to learn computer programming, can be a negative effect on the activation process [35]. Results reveal that gamified material can assist learners in obtaining a relevant understanding of programming and that they had less cognitive load for the mental load and mental effort.

(3) Data structure

Table 7 shows students' cognition load when using the gamified instruction. Lower scores were found in mental load for Q1 ($t = -6.43$), Q2 ($t = -7.42$), Q3

($t = -7.65$), Q4 ($t = -8.56$), and Q5 ($t = -9.35$) and mental effort for Q6 ($t = -9.20$), Q7 ($t = -9.16$), and Q8 ($t = -10.78$). Participants' cognition load was quite below the average scale. Some studies reported that visual display aids to reduce cognitive load [36, 37]. In the data structure learning activity, participants obtained a lower cognitive load than that of the programming and database management units.

5.3 System performance evaluation

System efficiency was measured after participants finished the learning activities. We examined the significance of each dimension of the IS success model. Each dimension was rated from 1 point to 5 points. Table 8–10 demonstrates the results of the system evaluation based on the IS success model on

Table 7. Results of cognitive load on the data structure unit

Cognitive load	N	Mean	SD	t-value	Sig.
Mental load	46				
Q1		1.93	1.12	-6.43	0.000
Q2		1.85	1.05	-7.42	0.000
Q3		1.76	1.10	-7.65	0.000
Q4		1.74	1.00	-8.56	0.000
Q5		1.76	0.90	-9.35	0.000
Mental effort					
Q6		1.74	0.93	-9.20	0.000
Q7		1.80	0.88	-9.16	0.000
Q8		1.72	0.81	-10.78	0.000

$p < 0.05$.

Table 8. T-test results of system efficiency on database management unit

DeLone & McLean IS success model	N	Mean	SD	t-value	Sig.
system quality	46	3.72	0.72	6.76	0.000
information quality		3.83	0.80	7.03	0.000
system use		3.91	0.91	6.77	0.000
user satisfaction		3.85	0.84	6.83	0.000
service quality		3.57	0.91	4.21	0.000
net benefits		3.67	0.97	4.73	0.000

$p < 0.05$.

Table 9. T-test results system efficiency on programming unit

DeLone & McLean IS success model	N	Mean	SD	t-value	Sig.
system quality	46	3.48	0.96	3.38	0.002
information quality		3.48	1.01	3.23	0.002
system use		3.46	1.11	2.79	0.008
user satisfaction		3.54	1.03	3.59	0.001
service quality		3.59	0.93	4.27	0.000
net benefits		3.67	0.82	5.59	0.000

$p < 0.05$.

Table 10. T-test results of system efficiency on data structure unit

DeLone & McLean IS success model	N	Mean	SD	t-value	Sig.
system quality	46	3.83	0.77	7.29	0.000
information quality,		3.87	0.83	7.08	0.000
system use		3.83	0.74	7.58	0.000
user satisfaction		3.89	0.85	7.12	0.000
service quality		3.83	0.82	6.79	0.000
net benefits		3.87	0.88	6.67	0.000

$p < 0.05$.

Table 11. Descriptive data and ANCOVA result for the post-test scores

		N	Means	SD	Adjust mean	Std. error	F value
Post-test	Experiment Group	49	77.35	13.15	78.37	1.48	6.93
	Control Group	49	73.88	15.04	72.86	1.48	

$p < 0.05$.

database management, programming, and data structure units. In the database management, the mean of system quality, information quality, system use, user satisfaction, service quality, and net benefits are 3.72, 3.83, 3.91, 3.85, 3.57, and 3.67, respectively (see Table 8). The results suggest that participants were considerably satisfied with the gamified instruction, especially with its practicality in database learning. In the programming unit, the mean of system quality, information quality, system use, user satisfaction, service quality, and net benefits are 3.48, 3.48, 3.46, 3.54, 3.59, and 3.67, respectively (see Table 9). In the data structure unit, the mean of system quality, information quality, system use, user satisfaction, service quality, and net benefits are 3.83, 3.87, 3.83, 3.89, 3.83, and 3.87, respectively (see Table 10).

These results suggest that the CSLS obtained a significantly high level of evaluation for each dimension of the IS success model; participants were satisfied with the functionality of the features provided by the CSLS. The means of integral satisfaction for database management, programming, and data structure are 3.76, 3.54, and 3.85, respectively.

5.4 Learning achievements of the students

The pre-test was employed in this study to confirm that the two groups of students had equivalent basic

knowledge required for taking this particular subject unit. The pre-test and post-test comprised 9 multiple-choice items with a full score of 100. It focused on evaluating the students' knowledge about database management, programming, and data structure. An independent t-test was used to analyze the pretest. The mean and standard deviation of the pretest were 72.44 and 15.05 for the control group, and 70.31 and 14.16 for the experimental group. As the p -value > 0.05 and $t = -1.04$, it can be inferred that these two groups did not significantly differ prior to the experiment. Table 11 shows the ANCOVA results of the posttest using the pretest as a covariate; the original means and standard deviations are also presented. From the posttest scores, it was found that the students in the experimental group had significantly better achievements than those in the control group ($F = 6.93$, $p < 0.05$).

6. Discussion

Many studies have discussed the efficiency of gamification [12], and some have reported that gamification implementations enhance students' learning motivation [38–39] and their learning performance [32, 38]. Recently, students' cognition using digital games has begun to attract considerable attention.

Sung et al. investigated the effect of digital games on students' cognition and affection [26]. The present study showed that gamification benefits cognitive load and technology acceptance in computer science education. However, there are a few limitations of this study. First, the game scenario did not allow for collaboration.

Collaborative learning is perceived as an effective vehicle for students to communicate with one another because they learn together by exploring questions or creating meaningful projects. Second, individual presence may influence motivation; the presentation of the game scenario should therefore adapt to students' preferences rather than providing a fixed expression type. To overcome these problems, we aim to develop multiplayer games that can connect social applications (Facebook and Twitter) with personal scenario mechanisms and incorporate these into the game, which will allow the material to adapt to the individual learner in future projects.

7. Conclusion

In this study, an online gamified learning environment was developed by integrating PBL concepts. In addition, this study examined how the proposed system affected learners' mental reflection in acquiring computer science knowledge. The results of the experiment demonstrate that CSLS promotes acceptance of technology. Furthermore, this study illustrates reduced cognition load regarding the proposed game approach on the data structure, programming, database management unit. According to the results of learning performance, this study indicated that learners who interacted with CSLS performed better than learners who did not. Concerning system performance, the CSLS obtained positive evaluation on the basis of the IS model consisting of six dimensions: system quality, information quality, system use, user satisfaction, service quality, and net benefits. In summary, the use of the PBL and gamification to support the computer science learning activity not only enhanced students' engagement but also improved the learning achievements of the students in learning computer science.

References

1. S. Deterding, D. Dixon, R. Khaled and L. Nacke, From Game Design Elements to Gamefulness: Defining Gamification, *In Proceedings of the 15th International Academic Mind-Trek Conference: Envisioning Future Media Environments*, ACM, September 2011, pp. 9–15.
2. A. Domínguez, J. Saenz-de-Navarrete, L. De-Marcos, L. Fernández-Sanz, C. Pagés and J. J. Martínez-Herráiz, Gamifying Learning Experiences: Practical Implications and Outcomes, *Computers & Education*, **63**, 2013, pp. 380–392.
3. T. M. Connolly, E. A. Boyle and E. MacArthur, T. Hainey, & J. M. Boyle, A Systematic Literature Review of Empirical Evidence on Computer Games and Serious Games, *Computers & Education*, **59**(2), 2012, pp. 661–686.
4. C. E. Hmelo-Silver, Problem-based Learning: What and How Do Students Learn? *Educational Psychology Review*, **16**(3), 2004, pp. 235–266.
5. J. C. Perrenet, P. A. J. Bouhuijs and J. G. M. M. Smits, The Suitability of Problem-based Learning for Engineering Education: Theory and Practice, *Teaching in higher education*, **5**(3), 2010, pp. 345–358.
6. E. Kroski, 7 Ed Tech Trends to Watch in 2014, *Open Education Database (OEDB)*, ACM, 2014. <http://oedb.org/ilibrarian/7-ed-tech-trends-watch-2014/>
7. R. N. Landers, K. N. Bauer, R. C. Callan and M. B. Armstrong, Psychological Theory and the Gamification of Learning, *In Gamification in Education and Business Springer International Publishing*, 2015, pp. 165–186.
8. L. De-Marcos, A. Domínguez, J. Saenz-de-Navarrete and C. Pagés, An Empirical Study Comparing Gamification and Social Networking on E-Learning, *Computers & Education*, **75**, 2014, pp. 82–91.
9. A. Rapp, Beyond gamification: Enhancing User Engagement Through Meaningful Game Elements, *In FDG*, 2013, pp. 485–487.
10. R. Christensen, D. A. Garvin and A. Sweet, Education for Judgment: The Artistry of Discussion Leadership, Cambridge, Mass.: Harvard Business School, 1991.
11. M. Ibanez, A. Di-Serio and C. Delgado-Kloos, Gamification for Engaging Computer Science Students in Learning Activities: A Case Study, *IEEE Transaction on Learning Technologies*, **7**(3), 2014, pp. 291–301.
12. J. Hamari, J. Koivisto and H. Sarsa, Does Gamification Work?—A Literature Review of Empirical Studies on Gamification, *In System Sciences (HICSS), 2014 47th Hawaii International Conference on*, January 2014, pp. 3025–3034, IEEE.
13. K. Huotari and J. Hamari, Defining Gamification: A Service Marketing Perspective, *In Proceedings of the 16th International Academic MindTrek Conference*, October 3–5, 2012, Tampere, Finland, ACM, pp. 17–22.
14. W. H. DeLone, The DeLone and McLean Model of Information Systems Success: A Ten-Year Update, *Journal of management information systems*, **19**(4), pp. 9–30, 2003.
15. S. Y. Park, An Analysis of the Technology Acceptance Model in Understanding University Students' Behavioral Intention to Use E-learning, *Journal of Educational Technology & Society*, **12**(3), 2009, pp. 150–162.
16. H. C. Chu, G. J. Hwang, C. C. Tsai and J. C. R. Tseng, A Two-tier Test Approach to Developing Location-aware Mobile Learning Systems for Natural Science Courses, *Computers & Education*, **55**(4), 2010, pp. 1618–1627.
17. M. Yi and Y. Hwang, Predicting the Use of Web-based Information Systems: Self-efficacy, Enjoyment, Learning Goal Orientation, and the Technology Acceptance Model, *International Journal of Human-Computer Studies*, **59**, 2003, pp. 431–449.
18. D. Persico, S. Manca and F. Pozzi, Adapting the Technology Acceptance Model to Evaluate the Innovative Potential of E-learning Systems, *Computers in Human Behavior*, **30**, 2014, pp. 614–622.
19. S. S. Liaw, Investigating Students' Perceived Satisfaction, Behavioral Intention, and Effectiveness of E-learning: A Case Study of the Blackboard System, *Computers & Education*, **51**(2), 2008, pp. 864–873.
20. E. W. T. Ngai, J. K. L. Poon and Y. H. C. Chan, Empirical Examination of the Adoption of WebCT Using TAM, *Computers & Education*, **48**, 2007, pp. 250–267.
21. C. S. Ong, J. Y. Lai and Y. S. Wang, Factors Affecting Engineers' Acceptance of Asynchronous E-learning System In High-tech Companies, *Information and Management*, **41**, 2004, pp. 795–804.
22. C. C. Pan, G. Gunter, S. Sivo and R. Cornell, End-user Acceptance of a Learning Management System in Two Hybrid Large-sized Introductory Undergraduate Courses: A Case Study, *Journal of Educational Technology System*, **33**(4), 2005, pp. 355–365.

23. E. M. Van Raaij and J. J. Schepers, The Acceptance And Use of A Virtual Learning Environment In China, *Computers & Education*, **50**(3), 2008, pp. 838–852.
24. P. C. Sun, R. J. Tsai, G. Finger, Y. Y. Chen and D. Yeh, What Drives a Successful E-Learning? An Empirical Investigation of the Critical Factors Influencing Learner Satisfaction, *Computers & Education*, **50**(4), 2008, pp. 1183–1202.
25. K. A. Pituch and Y. K. Lee, The Influence of System Characteristics on E-learning Use, *Computers & Education*, **47**(2), 2006, pp. 222–244.
26. H. Y. Sung and G. J. Hwang, A Collaborative Game-Based Learning Approach to Improving Students' Learning Performance in Science Courses, *Computers & Education*, **63**(1), 2013, pp. 43–51.
27. F. G. Paas, Training Strategies for Attaining Transfer of Problem-Solving Skill in Statistics: A Cognitive-Load Approach, *Journal of educational psychology*, **84**(4), 1992, pp. 429–434.
28. J. Sweller, J. J. G. van Merriënboer and F. G. Paas, Cognitive architecture and instructional design, *Educational Psychology Review*, **10**(3), 1998, pp. 251–297.
29. S. Petter, W. DeLone and E. McLean, Measuring Information Systems Success: Models, Dimensions, Measures, and Interrelationships, *European Journal of Information Systems*, **17**(3), 2008, pp. 236–263.
30. D. R. McIntyre, H. C. Pu and F. G. Wolff, Use of Software Tools in Teaching Relational Database Design, *Computers & Education*, **24**(4), 1995, pp. 279–286.
31. S. Deterding, M. Sicart, L. Nacke, K. O'Hara and D. Dixon, Gamification. Using Game-Design Elements in Non-gaming Contexts, *In CHI'11 Extended Abstracts on Human Factors in Computing Systems*, ACM, May 2011, pp. 2425–2428.
32. M. Papastergiou, Digital Game-Based Learning in High School Computer Science Education: Impact on Educational Effectiveness and Student Motivation, *Computers & Education*, **52**(1), 2009, pp. 1–12.
33. F. Liu, M. C. Chen, Y. S. Sun, D. Wible and C. H. Kuo, Extending the TAM model to explore the factors that affect Intention to Use an Online Learning Community, *Computers & Education*, 2010, **54**(2): pp. 600–610.
34. R. D. Pea and D. M. Kurland, On the Cognitive and Educational Benefits of Teaching Children Programming: A Critical Look, *New Ideas Psychol.*, **2**, 1984, pp. 147–168.
35. R. Mayer, The Psychology of How Novices Learn Computer Programming, *Comput. Surv.*, **13**, 1981, pp. 121–141.
36. D. Uttal and C. Cohen, Spatial thinking and STEM Education, When, Why and How? *The Psychology of Learning and Motivation*, **57**(1), 2011, pp. 147–181.
37. M. Jones, G. Gardner, A. Taylor, and E. Wiebe, Conceptualizing Magnification and Scale: The Role of Spatial Visualization and Logical Thinking, *Research in Science Education*, **41**(3), 2011, pp. 357–368.
38. G. J. Hwang, P. H. Wu and C. C. Chen, An Online Game Approach for Improving Students' Learning Performance in Web-based Problem-solving Activities, *Computers & Education*, **59**(4), 2012, pp. 1246–1256.
39. T. Y. Liu and Y. L. Chu, Using Ubiquitous Games in an English Listening and Speaking Course: Impact on Learning Outcomes and Motivation, *Computers & Education*, **55**(2), 2010, pp. 630–643.

Yu Hsin Hung is now a PhD student in Department of Engineering Science and Ocean Engineering from National Taiwan University. She is an information engineer with interests in educational technology, mobile application design, artificial intelligence, and web technology; she is now an adjunct instructor in Department of Computer Science and Information Management of Soochow University. Her current research interests include educational technology, multimedia and data mining.

Ray I Chang received his Ph.D. degree in Electrical Engineering and Computer Science from National Chiao Tung University in 1996, where he was a member of the Operating Systems Laboratory. As his Ph.D. degree was pursued, he joined the Computer Systems and Communications Laboratory of the Institute of Information Science, Academia Sinica. In 2003, he joined the Department of Engineering Science, National Taiwan University. Dr. Chang has published over 180 original papers in international conferences and journals. His current research interests include machine learning, multimedia networking and data mining. Dr. Chang is a member of IEEE, CERP and IICM.

Chun Fu Lin received the PhD degree in the Department of Engineering Science and Ocean Engineering from National Taiwan University, Taipei, in 2014. Dr. Lin is interested in engineering education; he has published over twenty original papers about educational technology in international conferences and journals. Dr. Lin is a member of CDMS, and CSIM.