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A Data Structure Learning System for Investigating the Effects of Different Learning Styles on Learning Performance

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Abstract: Information and communications technology (ICT) has developed rapidly with computer assisted systems and has been applied in many industries. Because of the development of ICT, digital literacy has been recognized as an essential competency in the 21st century. In computer sciences, data structures are critical for system performance improvements. This study developed a data structure learning system (DSLS) with puzzled- and game-based learning being employed for the learning scenario. Game-based learning has been shown to enhance learning motivation and performance, and puzzle-based learning is an innovative learning approach designed to develop problem-solving skills. Our DSLS focuses on engaging the learner and promoting self-reflection by offering a personalized scenario mechanism, so that learners are able to create their own learning scenarios, problems, and solutions in the data structure learning activities. Sixty-five participants were included in this study, the purpose of which was to explore the relationship between learning styles and learning performance in DSLS. The participant's mental efforts and learning attitudes toward data structure education were also included, the purpose of which was to examine the effectiveness of the data structure learning activity. The analysis results showed that the learners were able to improve their learning performance and perception using DSLS.
Keywords: Game-based learning, learning attitude, learning styles, puzzle-based learning

1. Introduction

Problem-solving skills are now considered to be one of the core competencies in science education. Data structures employ mathematical, programming, and logical knowledge to enhance processing efficiency by organizing or implementing data of a particular abstract data type to solve computer performance problems. There-fore, logical reasoning abilities, which are essential for problem-solving, are necessary to understand data structure proposals [1]. The development of good data structure concepts typically requires students to do significant programming practice, which cannot be sustained unless they are adequately motivated.

Useful systems with good data structures can enhance applications and services. Therefore, designing adaptive, easy to understand data structure concepts is essential to success, which is the focus area of this study. Game-based learning, which involves problem-solving activities, is now considered an important e-learning mechanism for science education. Many researchers have used game-based learning to teach different science courses [2], such as math [3] and operating systems [4], [5]. In this game-based learning research, the main goal has been to improve learner motivation and interest. However, cognitive material loads can affect both the attitude toward learning and learning performance. Our study reports on a preliminary study that investigated the personal factors affecting learning per-romance in data structure learning activities. In this study, we developed a data structure learning system (DSLS) made up of an animated game and a personalized scenario mechanism to assist learners in under-standing data structure concepts. A series of problem-solving tasks based on puzzle and game-based learning were included in this data structure learning game. DSLS was primarily developed to teach data-structure concepts, problem-solving abilities, and to encourage self-reflection. The goals of this study were as follows:
(1) To develop game tools to teach the fundamental concepts of data structure learning.
(2) To determine learner attitudes toward DSLS learning and the cognitive loads required.
(3) To explore whether learning styles are associated with learning performance in the game-based data structure learning activities.

This section introduces DSLS and describes the survey instruments used to measure the relationship between learning styles and learning performance in the data structure learning activities. Section II reviews puzzle-based learning, game-based learning, and current computer science education. We then describe the develop-met and design of our DSLS puzzle game, animated-game, and personalized scenario. In Section III, we de-scribe how the aspects of puzzle- and game-based learnings were incorporated in DSLS. Section IV describes the experiment, and Section IV investigates the differences between learning performance, learning styles, and learning attitudes in data structure education. Finally, Section VI provides a discussion and con-occlusions, and outlines areas for future research.

2. Related Studies

2.1 Game- and Puzzle-based Learnings for Problem Solving

Programming and data structure processing are related to problem-solving abilities, which are essential in science education. Problem solving plays an important role in many domains from social science to business administration to computer programming. Many problems occur in a person's daily life, so the ability to deal with these problems may enhance learning performance and competence. In recent years, puzzle-based learning has been recognized as an important learning approach in critical thinking, problem-solving, and analytical thinking skills training [6], [7], [8]. Falkner, Raja, and Zbigniew (2010) indicated that educational puzzles can engage students when learning complex engineering programs and computer science. In engineering education, the goal of puzzle-based learning is to encourage learners to be effective computer science problem solvers in the real world [8]. Merrick's findings reported that puzzled-based learning was able to change the learning experience through the development of critical thinking skills and by increasing student interest and participation in the curriculum [7]. In Google, Microsoft, and Yahoo, computer science abilities, puzzle and problem solving skills are all position selection criteria [9]. Puzzle-based learning has three main characteristics: (1) puzzles are engaging and thought-provoking, (2) puzzles can be widely applied using different techniques, and the learning scenarios can be designed to emulate real-world problems, and (3) puzzles involve powerful and useful problem-solving rules in an entertaining format [6]. Problem-solving is essential in science education for subjects such as computer programming [10] and chemistry [11]. As problem-solving instructional materials can be designed in many formats and at varying difficulty levels, researchers have incorporated puzzle- and game-based learnings in many learning activity designs [12].

Applying game-based learning has attracted considerable attention from researchers [13], [14], [15], as these games offer a meaningful problem-solving framework [15], [16] and have the ability to engage the learner. Research has found that games have a positive effect on students' reasoning performance and can enhance learning performance [17], [18]. Furthermore, game-based learning has been found to be an effective approach to improve learner performance by promoting meaningful interactions between students during the gaming process [19]. Moreover, as this game-based learning most often requires problem solving, learners are engaged and motivated to solve these problems to progress in the game [20]. Studies have found that the playing of games leads to a "flow" state because games have challenges, clear goals, rules, and a sense of achievement [21], so learners are able to extrapolate the abstract concepts to the concrete game experience in an attempt to solve problems [22]. One major advantage of game-based learning has been the enhancement of learner collaboration [21], [23] through which the learners have the opportunity to construct their own learning experiences and thereby acquire a deeper understanding of the problem-solving skills in the game [24]. Over-all, learners who have used game-based learning and puzzle-based learning have shown higher motivation to complete the tasks and move forward in the game/learning.

2.2 Situated Learning, Personal Traits, and Science Education

Lave and Wenger (1991) proposed the situated learning theory as a way to overcome high-cognitive-load problems, which caused learners to lose their way in the learning process [25]. Situated learning was developed for teachers to give guidance in the design of authentic situated learning material or authentic teaching environments. Situated learning is a learner-centered theory that allows learners to adapt in a diverse but authentically related environment. Therefore, the essence of situated learning is participatory action learning, reflection, exploration, and feedback. Another important consideration in the learning process is the recognition of learning styles, which puts focus on an individual's learning preferences. These different learning styles involve numerous behavioral features, such as learning interest and learning processing and can be used to facilitate adaptive teaching strategies for the instructor and provide adaptive learning scenarios. An index of learning styles (ILS) was proposed by Felder and Solo-man who described eight different learning styles: visual, verbal, active, reflective, sequential, global, sensing, and intuiting [26]. For instance, in the sequential learning style, learners are involved with self-efficacy [27]. Learners with a global learning style are generally more creative, while reflective learners require situations that provide an opportunity to think for themselves [28]. These learning styles can affect problem-solving skills in different ways. Therefore, fulfilling an individual learner's learning requirements has been the focus of considerable research. A review of the related literature shows that learning styles have been increasingly incorporated in learning systems [29], [30], especially in science education.

Simulation is a key part of situated learning theory for the following reasons: (1) learners are not forced to learn but encouraged to create ideas, so they are excited by the learning process, and (2) simulations promote active learning [31]. To support this view, digital game-based simulations methodology has been used in science education for ocean ecology education [32] and mathematics skills development [33]. Lo et al. reported that when using situated learning, learners were able to use their experiences to obtain a more meaningful and better understanding of ocean ecology [32].

In the learning content of this study, puzzle mechanisms and game-based learning mechanism were integrated to develop data structure education learning material. As problem solving is important for science education, this puzzle mechanism can provide critical thinking skills training, which benefits problem solving. This study also employed ILS [26] to determine the students' learning styles and to explore the relationship between learning styles and learning performance.

3. Methodology

For this study, a DSLS was developed to conduct a hybrid learning approach using web techniques. The DSLS consisted of data structure learning games and a personalized scenario mechanism (Fig. 1). Each DSLS game was well defined and was designed with the goal of engaging learners in understanding data processing and data search. Puzzle- and game-based learnings were seen as essential phases in the data structure learning, so mazes and rearrangement puzzle problems were used for the game scenarios. As discussed, these diverse game-based problem contexts can enhance learner interest and performance. Using this approach, the learners completed the game tasks by applying their data structure knowledge to determine a solution. The personalized scenario mechanism was developed to promote active learning by allowing learners to create their own learning scenarios.

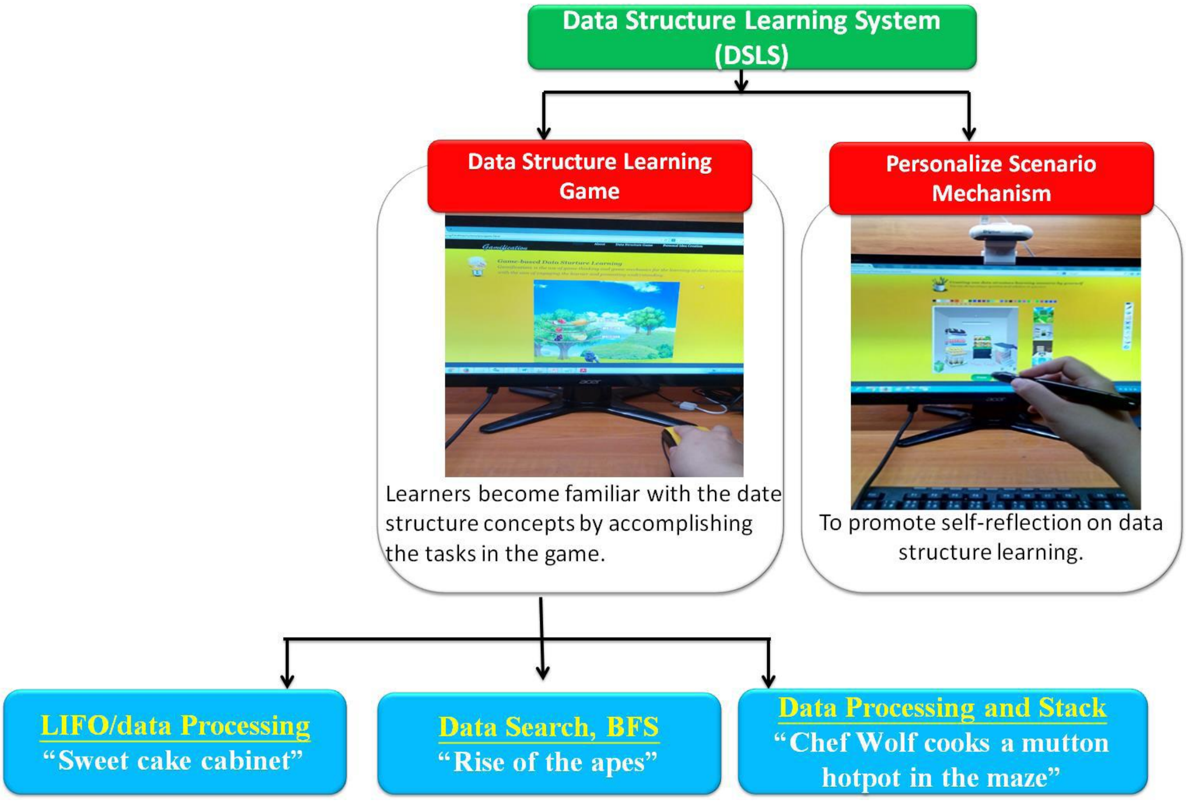

Figure1: DSLS interface.

3.1 Data Structure Learning Game

Animations are seen as appropriate for engineering instruction, as they are able to present fine-grained action. To illustrate data structure concepts using daily life examples helps the beginner understand the concepts more efficiently. In the gaming process, learners were asked to solve a problem using data structure concepts such as data processing and searching. For our study, we developed three simulation games for data structure learning: "Sweet cake cabinet," "Chef Wolf cooks a mutton hotpot in a maze," and "Rise of the Apes." These data structure learning games had two main training features: problem-solving and data structure learning, with data processing and searching being the main learning goals. The "Sweet cake cabinet" game focused on data rearrangement, “Chef Wolf cooks a mutton hot-pot in a maze” focused on data processing, such as pop and push, and “Rise of the Apes” was designed to assist the learner understand the breadth of a first search.

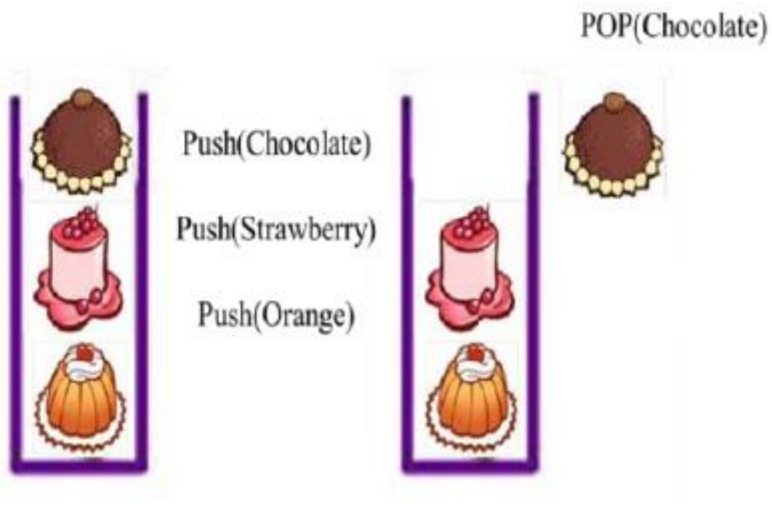

Figure 2: Interface of “Sweet cake cabinet.”

“Sweet cake cabinet” is a scenario-based game in which the learner has to rearrange the cake display with the purpose of getting a favorite cake as soon as possible. In this game, the clue is in the structure and arrangement of the cabinet. As people often buy cakes, learners would be familiar with the concept of cake stacks in a purchase scenario. Last in first out (LIFO) represents the data processing in a stack-type data structure; so in this simulation, the cake cabinet represents the stack. There are two ways to arrange the cakes, i.e., “taking-in” and “taking-out,” which corresponds to the data processing behavior of “pop” and “push.” In this scenario, learners need to determine how to efficiently get their favorite cake (Fig.2).

“Chef Wolf cooks a mutton hotpot in a maze” is a story about Chef Wolf who explores a maze to find the needed ingredients for a mutton hotpot. After the learners have practiced the basic stack concept, it is expected that they would be familiar with a stack application problem. In this problem-solving game, a puzzle-based mechanism is integrated. The forward and backward concept inte-grated in this game is associated with the push and pop in data processing behavior, respectively (Fig. 3).

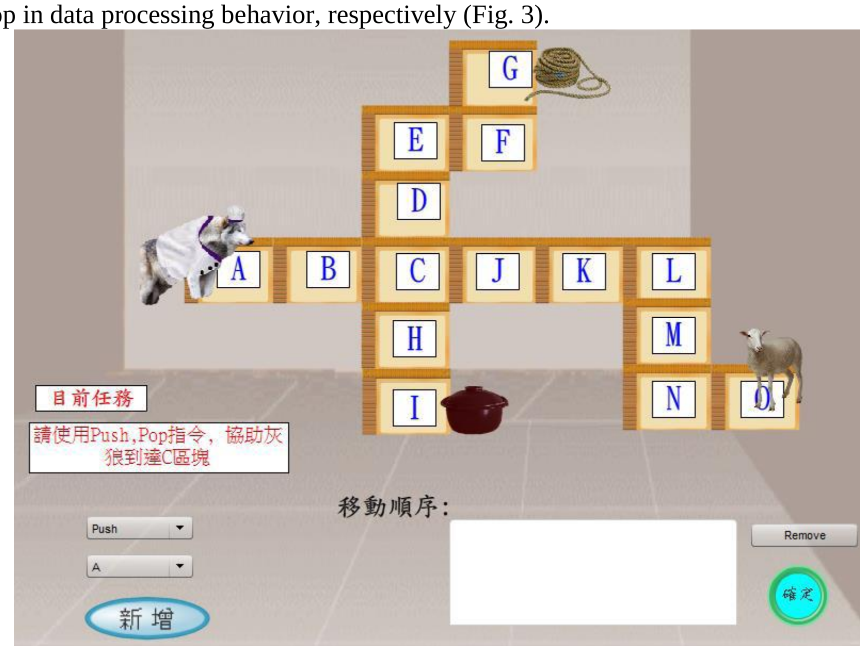

Figure 3: Interface of “Chef Wolf cooks a mutton hotpot in a maze.”

“Rise of the Apes” is a game in which an ape forages for fruit in a magic tree. Breadth-first search (BFS) is employed as one of the search strategies in this tree structure. To ensure that learners gain a deep impression of the BFS concept, we designed a three-level tree structure for the apes to find and pick their favorite fruit. Learners learn BFS through the animations and their interaction with the game (Fig. 4).

Figure 4: Interface for “Rise of the apes.”

3.2 Personalized Scenario Mechanism

Self-reflection and active learning are essential for DSLS, so learners’ creativity and imagination can be engaged when using and creating their own learning materials. Learners can not only develop their own data structure learning scenarios but also apply their data structure knowledge to these design problems and solutions using a personalized scenario mechanism. Fig. 5 shows a personalized learning scenario where the learner is required to provide an algorithm to order flowers. If a student wants to develop the data structure problem, they can select or create the preference scenario, and design a unique problem and solution.

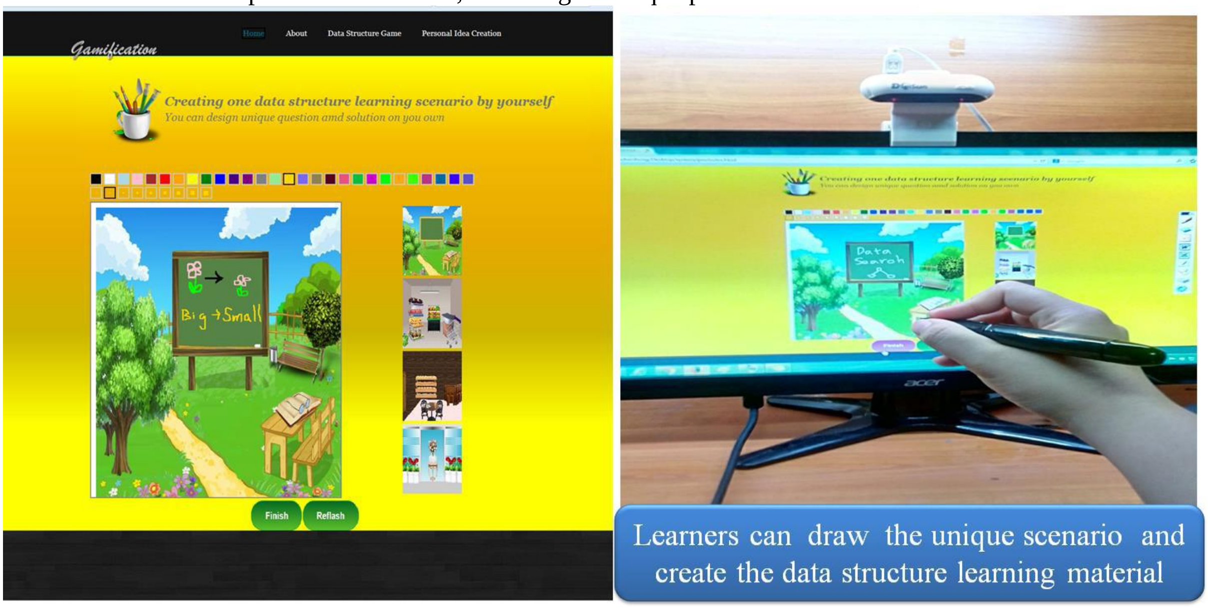

Figure 5: Personalized scenario mechanism.

4. Experiment

4.1 Participants and Experimental Procedures

In this study, we collected real data to illustrate that game-based problem solving can make the learners easier to learn data structure concepts. The data were obtained from 65 students who were beginners in learning about data structures. The participants completed the learning task in 40 min. The collected information is displayed in Table 1.

Table 1: The learning profile of the students. Variables	Description	Type
ID	Identify sample (N = 65)	Numerical
Age	18–24 years old (Mean = 22.14; S.D.=2.28)	Numerical
Learning style	Eight learning styles were assessed: active, reflective, sensing, intuitive, visual, verbal, sequential, and global.	Numerical
Learning performance in the data structure learning game	Each game was rated (0 or 1), and the total score for each scenario was 3 points. Three games were included in DSLS as follows: 1. “Sweet cake cabinet,” 2. “Chef Wolf cooks a mutton hotpot in a maze,” 3. “Rise of the apes.”	Numerical
Perception	Learning attitudes questionnaire [34] Mental effort questionnaire [35]	Numerical

Fig. 6 outlines the experimental procedure. Because the learners may have had little understanding of data structure and its application to real life, in the beginning a simple and life-related example was used to introduce the data structure concept. After introducing the importance of data structure, the participants were enrolled in the data structure game. These games were based on puzzle and game-based learning and each mini game had one data structure concept included in the unit goal, such as BFS or a stack application. When they had finished the game activities, participants completed a questionnaire to allow for an examination of their learning attitudes and mental effort. Finally, the experimental design included a brainstorming session, in which the participants applied creativity, imagination, and data structure concepts to the development of their own personal learning scenario.

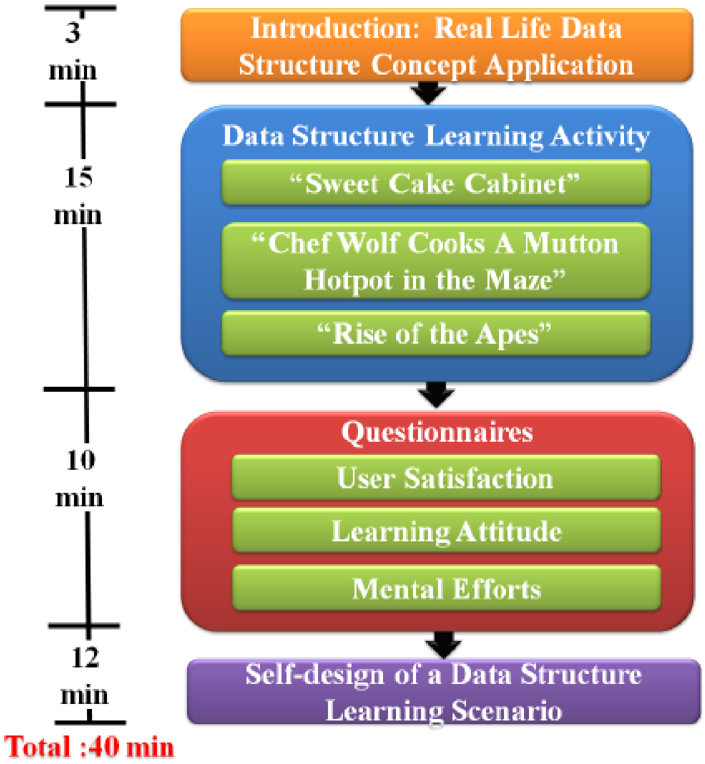

Figure 6: Experimental procedure.

4.2 Design of the Experiment

The participants were given the same game scenarios and data structure learning tasks. In the game, participants were asked to arrive at a solution by implementing the data structure concept. To ensure consistency in the game rating, a referee participated in the rating process, and the solution for each game scenario was scored as per the rating standards. For the game rating standards, if a learner successfully accomplished the task, they received one point. The game reliability showed a Cronbach's α value of 0.76. To explore whether learning styles had an influence on learning performance, ILS [26] was used to determine participants' learning styles, and the total accumulated game score was regarded as the indicator for learning performance. Understanding the learners' perceptions was essential, so a learning attitude questionnaire [34] and mental effort questionnaire [35] were employed. The mental effort questionnaire was modified by Sung and Hwang (2013) based on the cognitive load measures proposed by Paas (1992) [36] and Sweller, van Merriënboer, and Paas (1998) [37]. This study included open-ended questions about the personalized scenario, in which the learners could design their own data structure learning scenario.

5. Result

Previous research has shown that the use of multimedia material positively influences learning performance and generates positive emotions [39]. This study aimed to explore the impact of different learning styles on learning performance and to evaluate learning perceptions toward data structure education.

5.1 Effect of Different Learning Styles on Learning Performance

This study analyzed whether learning performance was affected by the eight learning styles. In the experiment, the learners in each learning style were classified in two categories, i.e., high level (top 50%) and low level (bot-tom 50%).

Table 2 indicates that learners with a high sensing ability had a significantly better performance in the data structure learning game than those with a lower sensing ability ($F(1, 64) = 7.35$, $p = 0.01 < 0.05$). In contrast, learners with a higher intuitive ability had a significantly lower performance than those with a lower intuitive ability ($F(1, 64) = 5.57$, $p = 0.021 < 0.05$). The data structure learning game presented a series of problem-solving scenarios to allow learners to use their own knowledge of the concepts to accomplish the task, with the results showing that those learners with a higher sensing ability had a better learning performance in the game. Felder et al. reported that the sensing learner prefers material, which emphasizes practical problem-solving methods [28]. Learners with a high visual ability had a better learning performance, whereas learners with a high verbal ability had a better learning performance in the animation game-based material ($F (1, 64) = 5.57$, $p = 0.021 < 0.05$). Diverse multimedia materials, such as animations, graphs, and pictures, were used to develop these data structure learning games. Some studies have shown that sensing or visual learners prefer visual materials (e.g., graphs, films, schematics, sketches, and pictures) [28]. In this study, those learners who were high visual learners or high sensing learners had a better learning performance.

Table 2: Result of learning performance based on different learning style.

Learning performance	Descriptive			ANOVA	
	Mean	SD	N	F	Sig.
Sensing					
High	2.49	0.64	39	7.35	0.01
Low	2.00	0.80	26		
Intuitive					
High	2.00	0.80	26	7.35	0.01
Low	2.49	0.64	39		
Visual					
High	2.47	0.66	34	4.30	0.04
Low	2.10	0.79	31		
Verbal					
High	2.10	0.79	31	4.30	0.04
Low	2.47	0.66	34		

5.2 Learner's Learning Attitudes, Mental Load, and Effort in the Data Structure Learning

The learning attitudes questionnaire items developed by Hwang and Chang [34] were used in this analysis. The learning attitude questionnaire consisted of 5 items: "The data structure concept is valuable and worth studying." (Q1); "It is worth learning those things about the data structure concept." (Q2); "It is worth learning the data structure concept well." (Q3); "It is important to learn more about the data structure concept." (Q4); "It is important to know the data structure concept." (Q5). The questionnaires were evaluated on a 7-point Likert-type scale: 1 = Strongly disagree; 2 = Disagree; 3 = Marginally disagree; 4 = Neutral; 5 = Marginally agree; 6 = Agree; 7 = Strongly agree. The results showed that the t-values were significant for Q1–Q5 ($p < 0.05$; Table 3), and the participants had a 95% chance of developing a high-level data structure learning attitude. The Cronbach's α value for the learning attitudes questionnaire was 0.92. The mental effort questionnaire consist-ed of two items to evaluate learners' perceptions, i.e., "I think the process of learning the data structure caused me a lot of pressure." (Q1); "I think I need to expend a lot of mental effort to accomplish the data structure learning." (Q2). The Cronbach's α value for the mental effort questionnaire was 0.92. Table 3 shows that the participants had a 95% chance of experiencing a low mental effort in the data structure learning.

Table 3: Result of learning attitude toward data structure

Item	N	Means	S. D.	t-value	p-value	Cronbach's α
Learning attitude						
Q1	65	4.94	1.23	5.831	0.000	0.916
Q2		5.14	1.12	7.666	0.000	
Q3		5.14	1.21	7.584	0.000	
Q4		5.00	1.24	6.515	0.000	
Q5		4.75	1.46	4.168	0.000	
Mental effort						
Q1	65	3.68	1.62	−6.58	0.000	0.918
Q2		3.57	1.71	−6.73	0.000	

5.3 Self-reflection about the Data Structure Learning Scenario

Many data structure examples exist in real life. To assist learners to be more creative in the future, we designed an open-ended questionnaire, which allowed participants to develop a data structure learning scenario or a real-life problem/solution (Fig. 7). Table 4 shows the participants real life data structure scenarios.

Table 4: Main scenario participants developed on their own.

Learning scenario	Data structure concept
"Planning the path from home to school and back again."	Path programming
"Going up and down the stairs."	Data processing
"Opening a door with many locks to escape a room."	Data search
"A Japanese sushi train."	Recursive
"A child plays Frisbee with a dog, repeats throws and catches."	Data processing
"Doing housework! How to place a dish efficiently on the bar."	Data arrange
"Sort through a pile of old clothes, the latest clothes will be taken first."	Data Sorting, LIFO
"Building the house by placing the bricks sequentially."	Data Sorting
"MRT station-The carriage is occupied in the rush hour."	Stack Full
"An airplane/train schedule."	Data Sorting
"After shopping in the supermarket, how the purchased food should be placed in the refrigerator according to a food catalog."	Data allocation
"Retro Snaker-A snake searches for food."	Search
"Finding a parking space."	Search
"The car towed first is the last car put down by the tow trunk."	Data Sorting, LIFO
"Playing a jigsaw puzzle."	Data search

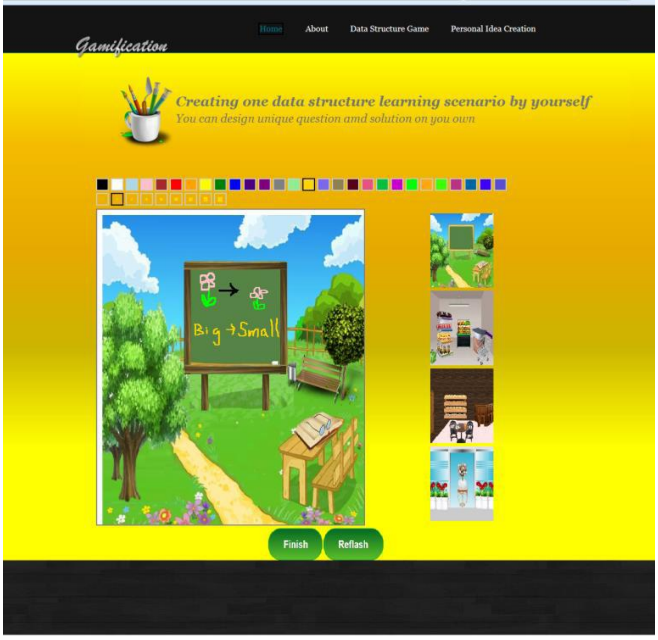

Figure 7: The self-deign scenario.

6. Conclusion

Feature identification may affect a learner's performance and affect teaching efficiency. Furthermore, a learner's performance may be influenced by learning styles. Graf et al. (2010) identified learning styles from learner behavior in an online course to develop educational adaptive systems [39]. From a learning performance viewpoint, our experiment has demonstrated that some learning styles are significantly related to learning performance. Our experimental results indicated that sensing and visual learners had a better performance in the data structure learning games—which consisted of problem-solving tasks and animation, which supports Felder's findings. Felder indicated that the sensing learner focuses on problem-solving and the sensing/visual learner prefers graphical material [28]. Other research has reported that digital games can promote student learning motivation [35], [40]. The results of our study confirmed this finding as learners reported that the game playing had a positive effect on their learning attitude and mental effort while learning about data structure.

This study contributes to puzzle-based and game-based learning system development for data structure education, and also identifies that learning styles can affect learning performance in data structure learning activities. From our results, we have determined that the following four dimensions are important factors for a DSLS:

1. Learner needs: Data structure is an important concept for computer science students. Learners are interested about the need to learn data structure and data structure applications in real life. Self-reflection offers the learner the ability to apply the knowledge by developing their own personal learning scenario content.
2. Teacher instruction: Teachers can assist learners by providing advice about the game process or the self-reflection activities. The main propose of gamification tools are to train the learner's active thinking and problem-solving abilities.
3. Suituted content: In the past, course content materials were usually designed for tests and examinations. However, these test designs were very difficult, leading to a lack of learner motivation. Therefore, content related to real life is designed for learners to make the learning process more entertaining.
4. Material diversification: While static material can be suitable for learners, game- and problem-based materials are a good approach for encouraging learners to develop more analytical skills. This study investigated the effect of innovative learning materials to allow learners to use their own specific learning strategies to accomplish the tasks.

However, there were several limitations to this study. First, some studies have indicated that different learning styles have different learning preferences, so the development of content related to characteristics of each learning style might benefit personalized learning. Second, we had a limited sample size, so it is difficult to claim that all findings were significant. To overcome these problems, future studies in this area could use different types of learning materials, such as audio and real-time celebration mechanisms in the data structure learning activities. Different content could also be used to investigate the correlation between the type of materials and learning styles. In the future, we plan to increase the sample size and include more important personal traits to enhance the personalized learning performance. Furthermore, as mobile devices are widely used in daily life, we plan to investigate how mobile applications can be incorporated in our proposed approach to allow learners to study and practice computer science knowledge anywhere.

Acknowledgement

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