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Interactive effects of scaffolding digital game-based learning and cognitive style on adult learners' emotion, cognitive load and learning performance

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Abstract

There has been a little research on emotion, cognitive load, or learning performance for digital game-based learning (DGBL). However, there is still a dearth of research on investigating the interactive effects of scaffolding DGBL and cognitive style on the above three outcomes. Participants were 97 middle-aged and elder adults from a community college and randomly assigned into three groups. Taking prior knowledge as the covariate, 3 × 2 two-way MANCOVA was adopted to verify the interactive effects of scaffolding DGBL (hard scaffolding DGBL, soft scaffolding DGBL, and non-scaffolding DGBL) and cognitive style (Serialist and Holist). The findings presented that there exited significantly interactive effects of scaffolding DGBL and cognitive style on learning emotion, cognitive load, and learning performance. In hard scaffolding DGBL, learning emotion, cognitive load, and learning performance of Serialist learners were significantly better than those of Holist learners. Conversely, in soft scaffolding DGBL, learning emotion, cognitive load, and learning performance of Holist learners were significantly better than those of Serialist learners. Learning emotion, cognitive load, and learning performance of Serialist learners using hard scaffolding DGBL and Holist learners using soft scaffolding DGBL were significantly better than those of learners using non-scaffolding DGBL. The findings demonstrated concrete contributions and implications on practical promotion and theoretical development. This study ensures sufficiency of applying the cognitive-affective theory of learning with media (CATLM), cognitive load theory and cognitive style theory on DGBL, suggesting to extend the application of these theories to scaffolding.

Keywords: Cognitive load, Cognitive style, Digital game-based learning, Learning emotion, Learning efficiency, Scaffolding

Introduction

The application of digital and interactive technologies (e.g., multimedia, game, etc.) in education has increased steadily over the past decades and many studies have presented the educational benefits of their use. However, a growing body of research shows that digital and interactive technologies have potential negative effects on children and adolescent physical, cognitive, emotional, and social well-being (Melo et al., 2020). Some studies argue that multimedia learning can decrease learner cognitive load and thus increase learning performance (Cheon & Grant, 2012; Korakakis et al., 2009). Digital game-based learning (DGBL) can decrease learner cognitive load and thus increase learning performance (Chang et al., 2017, 2018; Woo, 2014), does not cause significant cognitive load (Elford et al., 2022; Redlinger et al., 2022), sometimes does not affect performance (Redlinger et al., 2022), induce positive emotion towards collaborative problem solving (Rojas et al., 2022), and offer many benefits such as enhancing motivation, attitude, engagement, learning performance, success motivation, interest in the lesson, etc. (Alper et al., 2021; Eltahir et al., 2021). Gamification, applying game design principles to the context of education, increases learner enjoyment, experience, and involvement, as well as enhances learner motivation and performance (Melo et al., 2020). However, DGBL is complex and includes high realistic environment, high interactive interface, etc.; if these elements exceed users' cognitive capacity, DGBL will possibly lead to cognitive load (Korakakis et al., 2009; Schrader & Bastiaens, 2012). Digital games sometimes are used by adults for their informal learning and enhancing communication skills (Jin et al., 2019). However, there is still a dearth of research on DGBL aiming at adults (Tay et al., 2022). Whether digital games can decrease or increase adults' cognitive load still needs to be further explored.

Some studies reveal multimedia such as appropriate visual elements, shapes, colors, etc., produce positive emotion, increase learners' metacognition, learning motivation and interests, and further decrease cognitive load and enhance learning performance (Mayer, 2019; Plass et al., 2014, 2020; Um et al., 2012; Wong & Adesope, 2021). Especially, adults would use mobile devices to undertake their informal learning for affective and emotional needs on learning process (Jin et al., 2019). Multimedia in DGBL materials are more attractive and engaging than those in non-DGBL materials, yet DGBL materials sometimes are more frustrating in emotional state (Magana et al., 2022). Therefore, whether adults' emotion will be more positive in DGBL than that in non-DGBL because motivations and interests are enhanced still remains less explored at present.

Learning guidance, such as scaffolding, can be embedded to assist learners in completing learning tasks in DGBL to simultaneously enhance positive learning emotion, lower cognitive load, and increase learning performance (Kao et al., 2017; Sysoev et al., 2022), improve knowledge acquisition without simultaneously causing significant cognitive load (Zumbach et al., 2020), reduce negative effects of learning (Chang et al., 2022; Magana et al., 2022), and facilitate learning process and outcomes (Chen et al., 2020; Tay et al., 2022). However, previous studies on the effects of scaffolding in DGBL have reported inconsistent findings and demonstrate larger effect on adults/university students than on secondary school students (Cai et al., 2022). Hard scaffolding is usually shown as question prompts to guide learners, and soft scaffolding is mainly based on peer collaboration (Clark & Mayer, 2011; Sung & Hwang, 2013; Barzilai & Blau, 2014; Chen & Law, 2016; Saye & Brush, 2002). There have been some examples regarding hard and soft scaffolding in DGBL (Chang & Hwang, 2017; Chen & Law, 2016; Erhel & Jamet, 2013; Kao et al., 2017). Especially, adults can use technologies to develop their knowledge, share information and their feelings, and expand their social relationships by participating in online collaborative activities such as soft scaffolding (Jin et al., 2019). However, research on the impacts of hard and soft scaffolding to learners still remains inconsistent (Barzilai & Blau, 2014; Huang et al., 2015; Hwang et al., 2012), and remains unknown for adults.

Embedding scaffolding in DGBL, learners with different prior knowledge or cognitive styles intend to adapt to learning environments and get better learning performance (López-Vargas et al., 2017; Valencia-Vallejoet al., 2018). Owing to various cognitive styles, learners have different preferences on scaffolding (Ku et al., 2016). Some studies indicate, learners with various cognitive styles prefer different learning guidance and, in consequence, influence their learning performance (Chen et al., 2017; Huang et al., 2016). Cognitive styles will influence learners' learning preferences, cognitive processing, thinking styles, etc., and its impacts on DGBL should not be neglected (Chen & Liu, 2011; Ku et al., 2016). Contradictorily, many studies show no significant relationship between cognitive style and learning outcomes (Kirschner, 2017). Teachers believe students gain better learn outcomes when they receive information or instruction matching their cognitive style (Howard-Jones, 2014). Moreover, the cognitive-styles hypothesis of Pashler et al. (2009) presents a crossover interaction that learners with a specific cognitive type achieve better learning performance when adopting an teaching method matching their cognitive style (Kirschner, 2017). Similarly, some studies demonstrate interactive effects of between various learning methods and different cognitive styles on learning outcomes (Farag & Shemy, 2011; Höfflera & Schwartz, 2011); however, they did not take DGBL as a learning strategy.

According to the above research background, research gaps were summarized as follows: Whether DGBL could decrease or increase cognitive load still remained inconsistent for adults. The effects of hard and soft scaffolding on learning performance still remained uncertain for adults, and less comparisons among various scaffolding DGBL on emotion and cognitive load were developed. Some of previous studies explored the effects of various scaffolding and cognitive styles on learning performance, whereas less studies explored the interactive effects of DGBL and cognitive style on adults' learning emotion, cognitive load, and learning performance.

In order to fill the gaps, the study aimed to explore the interactive effects of scaffolding DGBL and cognitive styles about adults' learning emotion, cognitive load, and learning performance. The research questions are shown as follows: What are the interactive effects of scaffolding DGBL (hard, soft and non-scaffolding) and cognitive styles on learning emotion (positive and negative)? What are the interactive effects of scaffolding DGBL and different cognitive styles on cognitive load (intrinsic, extraneous, and germane cognitive load)? What are the interactive effects of scaffolding DGBL and different cognitive styles on learning performance (effect and efficiency)?

The importance of this study is to increase the comprehension about the interactive effects of scaffolding DGBL and different cognitive styles about adults' learning emotion, cognitive load, and learning performance, and to provide teaching practicers with references to design DGBL for adults.

Theoretical basis

Scaffolding theory and DGBL

Scaffold refers to an approach or mechanism by which learners obtain guidance or assistance from skilled or knowledgeable persons to go beyond the performance of Vygotsky's zone of proximal development to achieve tasks that are too difficult for them (Yelland &

Master, 2007). Scaffolding usually consists of teacher assistance, peer interaction, questions, and discussion in class, guiding learners to accomplish learning tasks and improve learning motivations and learning performances (Saye & Brush, 2002).

Barzilai and Blau (2014), and Liu and Israel (2022) suggested to "problematize" scaffolding in DGBL, combining learning tasks and knowledge in each stage and guiding learners to think and learn deeply step by step. Scaffolding mechanisms in DGBL are needed to guide learners' learning, as well as can enhance interactions of the game with learners and self-paced playing/learning in the game (Sysoev et al., 2022), and improve learning effectiveness (Chang et al., 2022). Zumbach et al. (2020) used cognitive and metacognitive prompting as the scaffolds in DGBL to support learner cognitive and metacognitive learning such as self-regulated learning. Chen et al. (2020) and Tay et al. (2022) indicated that scaffolds in DGBL can be the learning strategies to structure learner learning process. The meta-analysis of Cai et al. (2022) showed that scaffolding in DGBL could effectively enhance learning. If scaffolding does not guide learners to think deeply upon the learning content and is merely shown as an assistance to complete the game, the impact on learners would be quite limited.

Hard scaffolding is a kind of static supports; it tends to provide learners with uniform and conceptual assistance, and is hard to achieve adaptability. Soft scaffolding is a kind of dynamic supports, which is proper assistance provided by instructors or learner peers for some specific situation in the learning process (Saye & Brush, 2002). In DGBL, hard scaffolding guides learners through "their feedback and reflection on question prompts provided by learning environments." Soft scaffolding is based on instant learning supports or collaborative learning provided by instructors, making learners assist each other and the learning process work more smoothly (Chen & Law, 2016).

Some studies have shown that hard scaffolding DGBL could significantly improve learning motivations and performance (Chen & Law, 2016), and enhance learning attitudes, interests, and achievement (Hwang et al., 2012); nevertheless, some studies have claimed that hard scaffolding DGBL could not improve learning performance (Clark & Mayer, 2011). Some studies have argued that soft scaffolding DGBL could significantly improve learning attitudes, self-efficacy, and learning performance (Sung & Hwang, 2013), enhance learners' learning attitudes, motivations, collaborative skills (Chang & Hwang, 2017), and learning achievement (Chen & Law, 2016). However, all the above studies compare the differences between scaffolding (soft and hard) DGBL and traditional DGBL, rather than the differences between hard and soft scaffolding DGBL. In sum, the impacts of hard and soft scaffolding on learning remains inconsistent, their learning performance needs to be further explored.

Learning emotion theory and DGBL

Emotion is perceived by inner feelings when people face the outside environment, and further affects the comprehension of things (Feidakis et al., 2014). Pekrun et al. (2011) explained learning emotion is when learners face learning tasks, their inner feeling in the learning process and outcomes that are perceived from inner judgements. They divide learning emotion into positive and negative; if learners face positive learning environment, it would lead to positive emotion, and vice versa. Jin et al. (2019) argued that adults would associated affective and emotional needs with facilitating their spiritual learning using mobile devices. Therefore, learning environments play an important role for learners' learning emotion.

According to cognitive-affective theory of learning with media (CATLM) (Mayer, 2019), in multimedia learning environments, metacognition, motivation, affection, and attitude can be enhanced, and thus learners who invest proper cognitive resources to decrease extraneous cognitive load could increase cognitive performance. Nazry and Romano (2017), and Rojas et al. (2022) found learners obtained positive mood in DGBL. A good multimedia visual design will arouse learners' positive learning emotion, and then affect their learning performance (Um et al., 2012; Wong & Adesope, 2021). Poor design of digital game materials may inhibit learning motivations or cause learners' negative learning emotion (Plass et al., 2014, 2020) or result in frustrated emotion (Magana et al., 2022). At this moment, it is suggested to embed scaffolding to digital game learning materials. In this way, learners will get support and guidance, obtaining better learning performance. Soft scaffolding, such as collaborative learning, will arouse learners' positive learning emotion and decrease the frustration during digital learning (Du et al., 2016). Hard scaffolding DGBL, which integrates question prompts and learning content, can arouse learning motivations and enhance learning (Hawlitschek & Joeckel, 2017). All different scaffolding DGBL can arouse learning interests and enhance learning motivations, which provide learners with good learning experience (Chen & Law, 2016). To sum up, different scaffolding DGBL positively affect learning emotion, while what kind of scaffolding performs better still remains unknown.

Cognitive load theory and DGBL

Cognitive load refers to the load imposed on working memory when people deal with information. Cognitive load theory (CLT) designates, the cognitive capacity of working memory is limited; when cognitive load exceeds the extent that working memory could carry, it will cause cognitive overload and hinder the effect of cognitive processing (Clark & Mayer, 2019; Sweller, 2020).

Cognitive load is divided into three types (Sweller, 2020). Intrinsic cognitive load is the load generated from difficulty of the learning content. Therefore, intrinsic cognitive load is less likely to change through instructional design (Clark & Mayer, 2011). Extraneous cognitive load is mental load caused by how information is organized or weak instructional design (Leppink et al., 2014). Learners need to invest more cognitive resources to understand weak-designed messages or teaching materials, and thus increase mental efforts. Therefore, extraneous cognitive load can be decreased by good instructional design (Hawlitschek & Joeckel, 2017). Germane cognitive load is the mental efforts which learners invest to understand the learning content. Germane cognitive load can build automatic schema, which can store new information or knowledge to long-term memory, and decrease extraneous cognitive load (Sweller, 2020). That is, germane cognitive load is effective cognitive load.

The study of Chang's et al. (2018) presented DGBL outperformed non-DGBL on achievement and flow of college students as well as decreasing overall cognitive load. Chang's et al. (2017) study, based on media richness theory, argued DGBL was better than non-DGBL in college student flow experience and various types of cognitive load, meaning decreasing extraneous cognitive load and increasing germane cognitive load.

Woo (2014) found DGBL, embedding with system index (hard-scaffolding) and online discussion (soft-scaffolding), enhanced student motivation and performance outcomes, and decreased extraneous cognitive load and increased germane cognitive load. However, his study did not compare the differences on the above outcomes between hard-scaffolding and soft-scaffolding.

However, Managa et al. (2022) stated there were no statistically significant differences in intrinsic, extraneous, germane, and overall cognitive load, as well as cognitive effectiveness between DGBL and computer simulation. Zumbach et al. (2020) indicated that the provision of scaffolding (metacognitive prompting) in DGBL was effective in enhancing knowledge acquisition and reported a lower cognitive load, but not statistically significant. Redlinger et al. (2022) argued that game-like visual elements added to cognitive tasks caused neither significantly better performance nor significantly lower cognitive load. Elford's et al. (2022) findings indicated the significant improvement in spatial ability and academic performance of students when using Augmented Reality with DGBL elements. However, for cognitive load, spatial ability, and academic performance, the AR group does not outperform the control group (using two-dimensional drawings). Therefore, a balance between plentiful multimedia or game elements to prevent extraneous cognitive processing, and appropriate scaffolding mechanisms to enhance learning process with technologies, need to be taken into account.

Learning efficiency theory

Extending from the perspective of cognitive load, when learners involve in understanding the learning content in the learning process, the gap between their learning effect and cognitive load is defined as learning efficiency (Sweller et al., 2011; van Gog et al., 2012). The formula of learning efficiency is shown as below:

$$\mathrm{LE}_{\mathrm{fficiency}} = (\mathrm{LE}_{\mathrm{ffect}} - \mathrm{TCL}_{\mathrm{oad}})/\sqrt{2}$$

$\mathrm{LE}_{\mathrm{fficiency}}$: learners' learning efficiency after learning; $\mathrm{LE}_{\mathrm{ffect}}$: standardized Z score transferred from learners' learning effect after learning; $\mathrm{TCL}_{\mathrm{oad}}$: standardized Z score transferred from learners' total cognitive load in the learning process.

Before subtraction, learning effect and total cognitive load should be switched to standardized score (van Gog et al., 2012). The higher the learning effect (or the lower the total cognitive load), the higher the learning efficiency. If total cognitive load exceeds the learning effect, learning efficiency becomes minus value. The relations between learning efficiency and cognitive load are shown as below:

1. Positive or high learning efficiency ($E > 0$): learners' total cognitive load is lower than their learning effect.
2. Minus or low learning efficiency ($E < 0$): learners' total cognitive load is higher than their learning effect.

Under a high-efficiency learning environments, if learners have lower cognitive load, they will obtain higher learning effect (Misut & Pokorny, 2015). Many studies have shown that DGBL may improve learner learning performance (Alper et al., 2021;

Hussein et al., 2019). However, there is almost no any research or very little research that explores learner learning efficiency in DGBL.

Cognitive style theory

Cognitive style theory defines cognitive style as people's preferences when processing information in the face of the outside world; these preferences cause people's psychological differences, and apparently presented by attitudes, decisions, and habits, which in turn affect perception, memory, thoughts, and problem-solving patterns (Felder & Spurlin, 2005). As cognitive style theory indicates, well-matched cognitive styles make people have a better psychological feeling when interacting with the situation. Therefore, cognitive styles will influence how people develop their cognitive function, as well reaction and behavior patterns after receiving information (Ford & Chen, 2000). However, Kirschner (2017) argued, based on the findings of many experimental studies, cognitive styles will not influence learning outcomes and suggested to stop propagating the cognitive/learning styles myth.

Although there is no significant relationship between the preference for cognitive style and learning outcomes (Kirschner, 2017, p.169), teachers believe that students learn better when they receive information or instruction matching their preferred cognitive style (Howard-Jones, 2014). The learning-styles hypothesis of Pashler et al. (2009) observed a crossover interaction in which learners with a specific preference of cognitive type learn significantly better when adopting a teaching method matching their cognitive style; however, learners with a different specific or an opposing cognitive style probably learn worse when adopting the same teaching method not matching their cognitive style, but probably learn better when adopting the other teaching method matching their cognitive style (Kirschner, 2017).

Since cognitive styles involve one's personalities and broad aspects, there's no uniform standard to classify. Lee et al. (2005) applied cognitive style theory to learning, designated cognitive styles is preferences of people with different personalities to understand the learning contents during the learning process; these preferences tend not to be disturbed by the short-term outside world or other disturbing factors. Felder and Spurlin (2005) classified cognitive styles about learning to several dimensions, one of them is the way how people understand information, which is divided to Holist and Serialist dimension; both is the major dimensions that influence one's learning.

Holist learners prefer to learn broadly in a random, discontinuous way; Serialist learners prefer a narrowed view, learning in a logical and gradual way (Ford & Chen, 2000). Mampadi and Mokotedi (2012) found Holist learners tend to learn from broad to focus; Serialist learners tend to learn from detail to overall. Clewley et al. (2011) indicated, Holist learners prefer non-linear learning, and usually use the conceptual map to get an overview; Serialist learners prefer linear learning, and usually use index to obtain details.

As mentioned previously, cognitive style theory indicates, if learners adopt appropriate learning strategies, or their cognitive styles are compatible with the learning situation, they will consequently have a more positive learning experience and improve learning performance (Kirschner, 2017; Lee et al., 2005; Pashler et al., 2009; Thomas & McKay, 2010). Similarly, cognitive load theory claims, learners' traits will influence whether cognitive resources they invest would be positive and effective or not (Sweller, 2020). In sum, if cognitive styles are consistent with the learning strategy, it can reduce the waste of cognitive resources and extraneous cognitive load, increase germane cognitive load, and further improve learning performance. As some studies have indicated, various digital learning environments and different cognitive styles have interactive effects on learning emotion (Augustin, 2016; Beckmann et al., 2015), cognitive load (Höffler & Schwartz, 2011), and learning performance (Chen et al., 2005; Chen & Chang, 2016; Höffler & Schwartz, 2011). However, the research above did not aim at scaffolding or DGBL.

As Clewley et al. (2011) pointed out, Holist learners prefer collaborative learning and peer discussion (soft scaffolding), while Serialist learners prefer index and question prompts (hard scaffolding). Huang et al. (2016) found that, in digital learning environments, Holist learners had higher learning emotion than Serialist learners when using a concept map as scaffolding guidance; when using an index as scaffolding guidance, Serialist learners had higher learning emotion than Holist learners. Nonetheless, the above research did not take DGBL as a learning strategy, neither did they explore the interactive effects of cognitive styles and learning strategies.

Methods

Participants

This study adopted convenient sampling, recruiting three extra classes in an adult continuing community college. Learners registered voluntarily the learning activity and were randomly assigned into the three classes. There were 97 people in total, including 68 females and 29 males with a mean age of 61 (SD = 8.9). The experimental I used hard scaffolding DGBL, including 34 people (20 females and 14 males); the experimental group II used soft scaffolding DGBL, including 31 people (25 females and 6 males); the control group used non-scaffolding DGBL, including 32 people (23 females and 9 males). There were 79 people who had experienced in using computers, and all learners would be introduced how to operate computers and digital materials before the experiment. These adult learners were strong desire and expectance to learn, accumulated learning experiences, autonomy and self-directed learning, problem-solving base to learning, resilience and persistence, etc., that conform to internal and external factors of adult learning (Merriam et al., 2020).

Research design and framework

This study adopted the experimental approach with design of pretest–posttest control group, shown as Table 1. Three groups were requested to have pretests about water-saving prior knowledge, cognitive style, and learning emotion before the experiment. After the experiment, posttests about water-saving, learning emotion, and cognitive load were given. The three group adopted different learning methods with the same learning

Table 1 Experimental design

Group	Pretest	Experimental treatment	Posttest
Control group Experimental group I Experimental group II	1. Water-saving prior knowledge 2. Cognitive style 3. Learning emotion	Non-scaffolding DGBL Hard scaffolding DGBL Soft scaffolding DGBL	1. Water-saving knowledge (learning effect) 2. Learning emotion 3. Cognitive load

content. Non-scaffolding DGBL group used the game material without any scaffolding mechanisms; Hard scaffolding DGBL group used the game material with static supporting mechanisms (e.g., feedback and reflection on question prompts); Soft scaffolding DGBL group used the game material with dynamic supporting mechanisms (e.g., collaborative learning via discussion online).

Data analysis

Taking prior knowledge as the covariate, 3×2 two-way MANCOVA was adopted to verify the interactive effects of scaffolding DGBL (three groups) and cognitive style (two groups) on learning emotion (positive and negative) and compare the differences among these groups; cognitive load (intrinsic, extraneous, and germane) and learning performance (effect and efficiency). The formula of learning efficiency transforming from learning effect is shown in section Theoretical basis.

Experiment procedure

The teaching experiment lasted two weeks, 120 min per week in a computer lab. In the first week, the teacher spent 60 min introducing learning objectives, water-saving prior knowledge, and computer operation. The last 60 min, the teacher explained the pretest rules, the way to answer, and the reminders, and then students took the pretest. In the former 80 min of the second week, the teacher illustrated how to use learning materials and reminders, and each group proceeded with different scaffolding DGBL. The teacher was responsible for assisting and supervising students when they were learning. The last 40 min, the teacher explained the posttest rules, the way to answer and the reminders, and then students took the posttest.

In terms of the experimental control, the teacher was the same person, and gave the same teaching and guidance. The learning content was the same in each group, and shared the identical schedule and time. The teacher informed and supervised the students, hard scaffolding DGBL learners were not allowed to discuss with peers; soft scaffolding DGBL learners were allowed to discuss in online synchronous discussion system. The above measures could improve the internal and external validity in the experiment.

Learning materials

Learning objectives

The overall learning objectives are to learn daily water-saving knowledge and skills; the learning objectives in each stage of the DGBL material are shown as Table 2.

Game

The game is mainly about the protagonist's daily life and involves the task-based learning approach. Game scenes include restroom, toilet, garage, gardens, bathroom, where water resources are usually used. This game takes five interactive stages (learning tasks), sequentially including brushing teeth, using toilets, washing cars, watering flowers, and showering, and learners will learn the knowledge about water-saving and how to save water through different tasks. Learners need to finish all five stages in sequential order shown as above to complete the experiment.

Table 2 Learning content in each stage of the DGBL material

Stage of game	Learning objectives
Brushing	1. Learn how to save water when brushing teeth 2. Learn how much water will be saved with various gargling ways
Toilet	1. Learn how to save water in the toilet 2. Learn how much water will be saved in the toilet 3. Learn the principles of how water-saving toilet works
Car-washing	1. Learn how to save water when washing cars 2. Learn how much water will be saved when washing cars 3. Learn the principles of how water-saving tools work
Flower-watering	1. Learn how to save water when watering flowers 2. Learn different water-saving ways to water flowers 3. Learn how much water will be saved when watering flowers
Showering	1. Learn how to save water when taking a shower and shampoo 2. Learn how much water will be saved when taking a shower and shampoo 3. Learn specific ways to save water in the bathroom

Besides, through different types of scaffolding, learners can choose proper water usages. When learners click on prompts (hard scaffolding) of each stage (Fig. 1), they will be guided to think and complete the task, as Fig. 2 (taking watering flowers in the garden as an example).

In each stage, learners can connect tlk.to, an online synchronous discussion system (soft scaffolding) (Fig. 1), to discuss about the question and complete the task, as Fig. 3. Learners can not only acquire knowledge from different scaffolding, but also complete learning tasks.

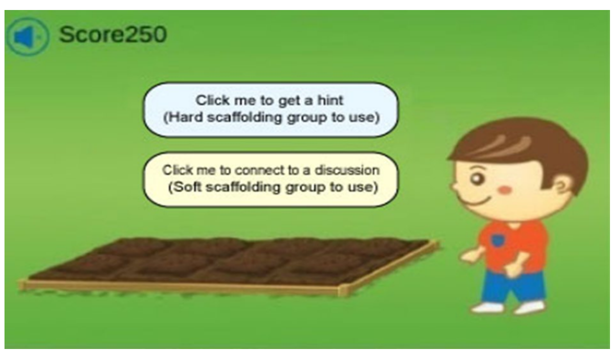

Fig. 1 Hard scaffolding- watering flowers in the garden. Notes: The prompt button of hard scaffolding will only be displayed for the hard scaffolding DGBL; the prompt button of soft scaffolding will only be displayed for the soft scaffolding DGBL

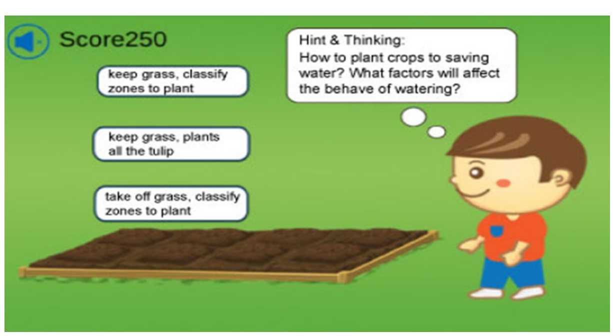

Fig. 2 Hard scaffolding- watering flowers in the garden

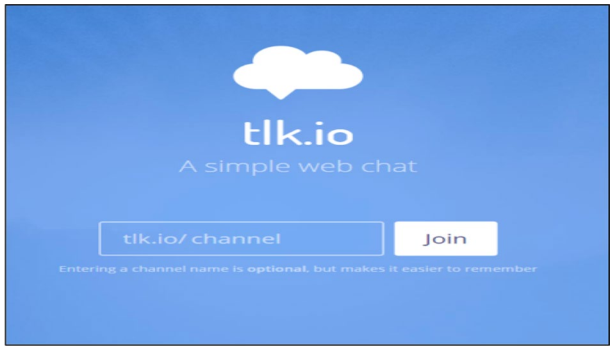

Fig. 3 Soft scaffolding

After learning tasks, the amount of daily water consumption will be calculated. The higher the score, the less the water consumption, and vice versa.

Parts of game elements by Prensky (2007) are taken to explain the DGBL material, and the reciprocal description is shown as Table 3 with Figs. 4, 5, and 6. The DGBL material is suitable for both the young and the old adults, and therefore their needs and preferences were not discriminated.

Table 3 Description of the water-saving game and game elements

Element	Water-saving game
Rule	This game is operated by "clicking." The player should click on "the best water-saving solution" to win scores. The rules are the same in each task, shown as Fig. 4
A sense of victory	When the player completes a task, he/she will be satisfied with his/her success. Through the final rank of water-saving score, learners could obtain the successful experience, and has a sense of satisfaction and pleasure, shown as Fig. 5
Competitiveness and challenge	The player can choose the best water-saving solution. When the player clicks on an improper method, he/she will consume more water, and the player will feel challenging. After completing all stages, the amount of water consumption and water saving of each player will be shown publicly and players can compare their scores. The rank will endow the game with a sense of competitiveness, shown as Fig. 6

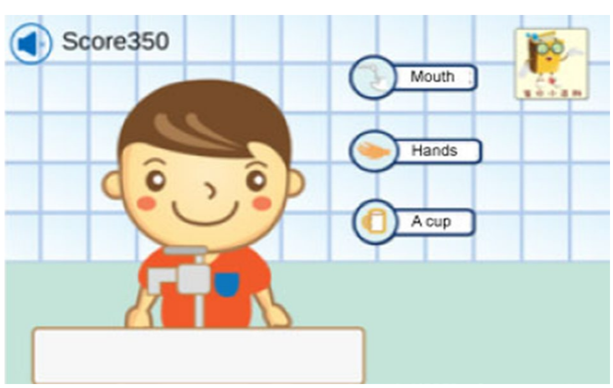

Fig. 4 Rule

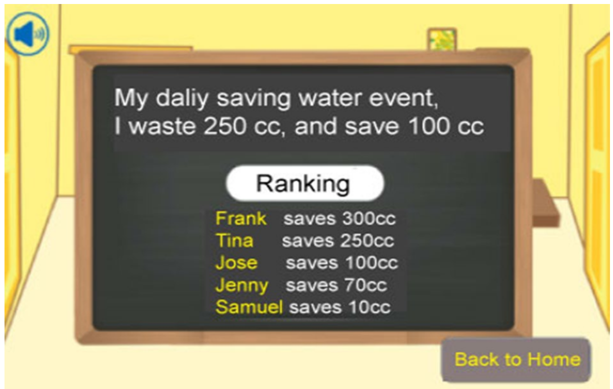

Fig. 5 A sense of victory

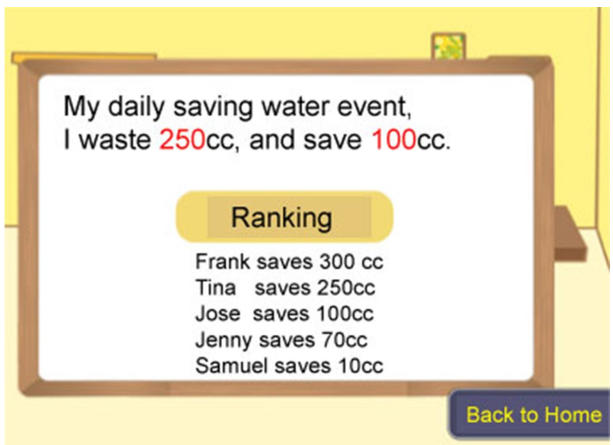

Fig. 6 Competitiveness and challenge

Instruments

Cognitive style questionnaire

Cognitive style questionnaire was adapted from Study Preferences Questionnaire (SPQ) by Jeske et al. (2014). Serialist type included 6 items; a sample item is: when reading, I would first review the whole content, and then begin to read. Holist type included 6 item, a sample item is: when reading, I would read the content in chapter order. The questionnaire adopted 5-point Likert-type scale. The construct with higher mean score was the cognitive style which learners prefer (Jeskeet al., 2014).

Since the factor loading of each item in the questionnaire was higher than 0.5, no items should be deleted. Eigenvalue of each construct in the questionnaire was higher than 1, which means each construct was validated; explained variance of each construct was higher than 50% (Serialist = 80.374%; Holist = 68.201%), revealing that the questionnaire was equipped with enough construct validity. Cronbach' α values of two constructs in the questionnaire were above 0.7 (Serialist = 0.808; Holist = 0.855), presenting that the questionnaire had enough reliability.

Learning emotion questionnaire

Learning emotion questionnaire was adapted from Achievement Emotions Questionnaire (AEQ) by Pekrun et al. (2011). Besides, referring to previous researches about positive and negative emotion (Park et al., 2015; Samsudin & Chng, 2015), those directly related to DGBL were added, such as interesting, peaceful, hatred, and unrelated to DGBL were deleted, such as pride, relief, and shame. Moreover, items and sentences were refined to correspond with the feature of the DGBL. The questionnaire adopted 5-point Likert-type scale. Positive emotion included 6 items; a sample item was that "the learning experiences made me feel interesting." Negative emotion included 6 items; a sample item was that "the learning experiences made me anxious."

Since the factor loading of each item in the questionnaire was higher than 0.5, no items should be deleted. Eigenvalue of each construct in the questionnaire was higher than 1, which means each construct was validated; explained variance of each construct was higher than 50% (positive and negative learning emotion = 71.894%, 65.823%), revealing that the questionnaire was equipped with enough construct validity. Cronbach' α values of two constructs in the questionnaire were above 0.7 (positive and negative learning emotion = 0.784, 0.731), presenting that the questionnaire had enough reliability.

Cognitive load questionnaire

According to different definition of cognitive load, and referring to the items by Leppink et al. (2014), this study developed the cognitive load questionnaire which applied to DGBL. Intrinsic cognitive load consisted of 6 items representing the complexity and difficulty of the learning content, the sample items included: I think the learning contents in this material were complex; I think the learning contents in this material were hard to understand. Extraneous cognitive load consisted of 6 items representing mental load generated by the organization of teaching materials and the presentation of media, the sample items included: the learning contents of this material did not display clearly; how this material was presented in media was ineffective to learn. Germane cognitive load consisted of 7 items representing learners' mental efforts on teaching materials, the sample items included: this material could make me concentrate on learning; this material could make me want to keep learning. The questionnaire adopted 5-point Likert-type scale.

Since factor loading of each item in the questionnaire was over 0.5, no items should be deleted. Eigenvalue of each construct in the questionnaire was higher than 1, which means each construct was validated; explained variance of each construct was higher than 50% (intrinsic, extraneous, and germane cognitive load = 65.237%, 68.378%, 64.682%), revealing that the questionnaire was equipped with enough construct validity. Cronbach' α values of three constructs in the questionnaire were above 0.7 (intrinsic, extraneous, and germane cognitive load = 0.827, 0.745, 0.869), presenting that the questionnaire had enough reliability.

Prior knowledge and learning effect test

There were 10 questions in the water-saving prior knowledge pretest. 20 multiple questions were included in the learning performance posttest, some of them were extended from the pretest.

The item analysis adopted the comparisons of extreme groups, applying *t*-test to compare the differences of each item from the two groups (the first 27% and the last 27% achievers). All *t* value was significantly reached, presenting each item had discrimination, and thus no items should be deleted. By means of Pearson's correlation, the correlation among each item and total scores reached significantly, revealing that each item had internal consistency, and thus no items should be deleted.

Difficulty index is $P=(P_h+P_l)/2$, and discrimination index is $D=P_h-P_l$. P_h means the percentage of the high achievers (the top 27%) answering correctly in each item; P_l means the percentage of the low achievers (the last 27%) answering correctly in each item. The knowledge posttest included 11 cognition questions, 1 affect question and 8 skill questions. Difficulty index ranged from 0.398 to 0.885; 11 questions were simple (>0.750), and difficulty index of 9 questions ranged from 0.398 to 0.724, which were moderate. The overall difficulty index was 0.736, and it ranges from 0.500 to 0.750, which were moderate and easy As for discrimination index, 6 questions were perfect (>0.400); 4 questions were good (0.300 ~ 0.400); 10 questions were fair (0.200 ~ 0.300). The overall discrimination index was good (0.368).

Results and discussion

Prior knowledge among learners with various cognitive styles reached significant difference ($t_{(95)}=-1.388$, $p>0.05$); Prior knowledge among learners with various scaffolding DGBL reached significant difference ($F_{(2, 94)}=3.236$, $p<0.05$), and prior knowledge of soft scaffolding DGBL was better than that of hard scaffolding DGBL ($p<0.05$). Hence, this study took prior knowledge as covariate, excluding its disturbance.

The interactive effect of scaffolding and cognitive style on learning emotion

Both Levene's test and homogeneity of regression test within groups were consistent with homogeneity assumption ($p>0.05$), and hence Two-way MANCOVA could be executed. Scaffolding groups and cognitive styles could at least have a significant interactive effect on either positive or negative emotion (Wilk's $\Lambda=0.577$, $p<0.001$). Both of them had significant interactive effects on positive learning emotion ($F_{(2, 1, 2, 90)}=22.719$, $p<0.001$, $\eta^2=0.335$), negative learning emotion ($F_{(2, 1, 2, 90)}=19.364$, $p<0.001$, $\eta^2=0.301$) and overall learning emotion ($F_{(2, 1, 2, 90)}=30.793$, $p<0.001$, $\eta^2=0.406$). The main effects of scaffolding groups on learning emotion were significantly reached (positive, negative, and overall learning emotion: $F_{(2, 93, 96)}=63.113$, $F_{(2, 93, 96)}=35.730$, $F_{(2, 93, 96)}=70.813$, $p<0.001$), but the main effect of cognitive styles on learning emotion was not significantly reached.

Simple main effects are shown as Table 4. The mean and standardized deviation of learning emotion between scaffolding groups and cognitive styles are shown as Table 5. When learners applied soft or hard scaffolding DGBL, learning

Table 4 Simple main effects of scaffolding DGBLs and cognitive styles on learning emotion

Emotion	Group	Source of variation	SS	MS	F	Sig	Post hoc test
Positive	Cognitive style	Non-scaffolding	0.157	0.157	1.764	0.194	
		Hard scaffolding	2.219	2.47	23.003	0.000***	Serialist > Holist ***
		Soft scaffolding	1.616	1.616	16.852	0.000***	Holist > Serialist ***
	Scaffolding	Serialist	7.002	3.501	34.811	0.000***	Hard scaffolding > non-scaffolding*** Soft scaffolding > non-scaffolding***
		Holist	10.465	5.232	60.987	0.000***	Soft scaffolding > non-scaffolding*** Soft scaffolding > hard scaffolding***
Negative	Cognitive style	Non-scaffolding	0.011	0.011	0.075	0.786	
		Hard scaffolding	2.785	2.785	21.400	0.000***	Holist > Serialist ***
		Soft scaffolding	2.438	2.438	17.649	0.000***	Serialist > Holist ***
	Scaffolding	Serialist	6.683	3.342	22.222	0.000***	Non-scaffolding > soft scaffolding *** > hard scaffolding ***
		Holist	9.456	4.728	37.930	0.000***	Non-scaffolding > hard scaffolding *** > soft scaffolding***
Overall	Cognitive style	Non-scaffolding	0.085	0.085	0.306	0.584	
		Hard scaffolding	10.863	10.863	40.013	0.000***	Serialist > Holist ***
		Soft scaffolding	8.036	8.036	25.864	0.000***	Holist > Serialist ***
	Scaffolding	Serialist	26.457	13.229	44.029	0.000***	Hard scaffolding > soft scaffolding*** > non-scaffolding***
		Holist	39.480	19.740	72.610	0.000***	Soft scaffolding > hard scaffolding*** > non scaffolding***

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 5 The mean and standardized deviation of learning emotion between scaffolding DGBLs and cognitive styles

Scaffolding DGBL	Cognitive style	N	Positive emotion		Negative emotion		Overall emotion	
			M	SD	M	SD	M	SD
Non-scaffolding	Serialist	15	3.506 (3.534)	0.361 (0.075)	2.386 (2.314)	0.478 (0.082)	6.121 (6.221)	0.721 (0.117)
	Holist	17	3.647 (3.671)	0.229 (0.071)	2.423 (2.447)	0.268 (0.077)	6.224 (6.224)	0.259 (0.110)
Hard scaffolding	Serialist	19	4.439 (4.364)	0.352 (0.074)	1.533 (1.503)	0.271 (0.085)	7.881 (7.861)	0.426 (0.124)
	Holist	15	4.040 (3.940)	0.307 (0.085)	1.933 (2.016)	0.392 (0.098)	6.743 (6.734)	0.621 (0.144)
Soft scaffolding	Serialist	15	4.329 (4.242)	0.258 (0.078)	1.919 (1.919)	0.415 (0.089)	7.319 (7.324)	0.483 (0.141)
	Holist	16	4.705 (4.702)	0.348 (0.076)	1.384 (1.374)	0.364 (0.086)	8.338 (8.327)	0.619 (0.137)

Number of Serialist and Holist = 49 and 48; Data in the parentheses was adjusted mean and adjusted standard deviation

emotion among various cognitive styles reached significant differences. When learners belong to Serialist or Holist cognitive styles ($N_s = 49$, $N_h = 48$), learning emotion among various scaffolding reached significant differences.

The interactive effect of scaffolding and cognitive style on cognitive load

Both Levene's test and homogeneity of regression test within groups were consistent with homogeneity assumption ($p > 0.05$), and hence Two-way MANCOVA could be executed. Scaffolding groups and cognitive styles could at least had a significant interactive effect on one of intrinsic, extraneous, or germane cognitive load (Wilk's $\Lambda = 0.823$, $p < 0.05$). Both of them had significant interactive effects on extraneous cognitive load ($F_{(2, 1, 2, 90)} = 3.698$, $p < 0.05$, $\eta^2 = 0.076$), germane cognitive load ($F_{(2, 1, 2, 90)} = 3.526$, $p < 0.05$, $\eta^2 = 0.073$) and total cognitive load ($F_{(2, 1, 2, 90)} = 6.627$, $p < 0.01$, $\eta^2 = 0.135$). The main effects of scaffolding groups on cognitive load were significantly reached (extraneous, germane, and the total cognitive load $F_{(2, 93, 96)} = 6.839$, $p < 0.01$; $F_{(2, 93, 96)} = 5.550$, $p < 0.01$; $F_{(2, 93, 96)} = 3.810$, $p < 0.001$), but the main effect of cognitive styles on cognitive load was not significantly reached.

Simple main effects are shown as Table 6. The mean and standardized deviation of cognitive load between scaffolding groups and cognitive styles are shown as Table 7. When learners applied soft or hard scaffolding DGBL, cognitive load among various cognitive styles reached significant differences. When learners belong to Serialist or Holist cognitive styles, cognitive load among various scaffolding reached significant differences.

Table 6 Simple main effects of scaffolding DGBLs and cognitive styles on cognitive load

Cognitive load	Group	Source of variation	SS	MS	F	Sig	Post hoc test
Extraneous cognitive load	Cognitive style	Non-scaffolding	1.076	1.076	2.168	0.151	
		Hard scaffolding	1.266	1.266	5.031	0.032*	Holist > Serialist*
		Soft scaffolding	1.963	1.963	4.754	0.037*	Serialist > Holist*
	Scaffolding	Serialist	3.259	1.629	4.632	0.015*	Non-scaffolding > hard scaffolding*
		Holist	8.561	4.281	10.277	0.000***	Non-scaffolding > hard scaffolding** Non-scaffolding > soft scaffolding***
Germane cognitive load	Cognitive style	Non-scaffolding	.144	.144	.259	0.615	
		Hard scaffolding	1.200	1.200	4.438	0.043*	Serialist > Holist*
		Soft scaffolding	1.275	1.275	4.775	0.037*	Holist > Serialist*
	Scaffolding	Serialist	1.982	.991	3.424	0.041*	Hard scaffolding > non-scaffolding*
		Holist	4.936	2.468	5.611	0.007**	Soft scaffolding > non-scaffolding**
Total cognitive load	Cognitive style	Non-scaffolding	1.042	1.042	.313	0.580	
		Hard scaffolding	2.403	2.403	2.128	0.154	
		Soft scaffolding	7.606	7.606	5.442	0.027*	Serialist > Holist*
	Scaffolding	Serialist	10.084	5.042	2.930	0.063	
		Holist	23.736	11.868	5.478	0.007**	Non-scaffolding > soft scaffolding**

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Table 7 The mean and standardized deviation of cognitive load between scaffolding DGBLs and cognitive styles

Scaffolding DGBL	Cognitive style	Intrinsic cognitive load		Extraneous cognitive load		Germane cognitive load		Total cognitive load	
		M	SD	M	SD	M	SD	M	SD
Non- scaffolding	Serialist	1.788 (1.786)	0.794 (0.144)	2.211 (2.163)	0.629 (0.175)	3.848 (3.872)	0.596 (0.160)	5.515 (5.345)	1.416 (0.351)
	Holist	1.648 (1.684)	0.754 (0.135)	2.579 (2.655)	0.765 (0.165)	3.714 (3.576)	0.857 (0.150)	5.513 (5.867)	2.119 (0.329)
Hard scaffolding	Serialist	1.799 (1.725)	0.704 (0.177)	1.627 (1.652)	0.429 (0.109)	4.331 (4.355)	0.465 (0.110)	4.091 (4.022)	0.991 (0.211)
	Holist	1.567 (1.629)	0.343 (0.135)	2.011 (2.099)	0.582 (0.127)	3.953 (3.843)	0.583 (0.128)	4.626 (4.885)	1.148 (0.245)
Soft scaffolding	Serialist	1.810 (1.778)	0.636 (0.073)	2.067 (2.059)	0.725 (0.160)	4.068 (4.084)	0.564 (0.127)	4.809 (4.753)	1.544 (0.257)
	Holist	1.728 (1.745)	0.467 (0.071)	1.563 (1.550)	0.556 (0.155)	4.474 (4.471)	0.469 (0.123)	3.812 (3.824)	0.690 (0.249)

Data in the parentheses was adjusted mean and adjusted standard deviation

The interactive effect of scaffolding and cognitive styles on learning performance

Both Levene's test and homogeneity of regression test within groups were consistent with homogeneity assumption ($p > 0.05$), and hence Two-way MANCOVA could be executed. Scaffolding groups and cognitive styles at least had a significant interactive effects on either learning effect or learning efficiency (Wilk's $\Lambda = 0.882$, $p < 0.05$). Both of them had significant interactive effects on learning effect ($F_{(2, 1, 2, 90)} = 5.200$, $p < 0.01$, $\eta^2 = 0.104$), learning efficiency ($F_{(2, 1, 2, 90)} = 3.210$, $p < 0.05$, $\eta^2 = 0.131$), and overall learning performance ($F_{(2, 1, 2, 90)} = 4.153$, $p < 0.05$, $\eta^2 = 0.147$). The main effects of scaffolding groups on learning performance were significantly reached (learning effect, learning efficiency, and overall learning performance ($F_{(2, 93, 96)} = 21.013$, $p < 0.001$; $F_{(2, 93, 96)} = 4.985$, $p < 0.01$; $F_{(2, 93, 96)} = 4.053$, $p < 0.01$), but the main effect of cognitive styles on learning performance was not significantly reached.

Simple main effects are shown as Table 8. The mean and standardized deviation of learning performance between scaffolding groups and cognitive styles are shown as Table 9. When learners applied soft or hard scaffolding DGBL, learning performance among various cognitive styles reached significant differences. When learners belong to Serialist or Holist cognitive styles, learning performance among various scaffolding reached significant differences.

Discussion

Research results revealed, in hard scaffolding DGBL environments, Serialist learners had significantly higher positive and overall learning emotion than those of Holist learners, and their negative learning emotion was significantly lower; in soft scaffolding DGBL environments, Holist learners had significantly higher positive and overall learning emotion than those of Serialist learners, and their negative learning emotion was significantly lower.

Table 8 Simple main effects of scaffolding DGBLs and cognitive styles on learning performance

Performance	Group	Source of variation	SS	MS	F	Sig	Post hoc test
Learning effect	Cognitive style	Non-scaffolding	0.028	0.028	0.000	0.988	
		Hard scaffolding	208.091	208.091	4.394	0.044*	Serialist > Holist *
		Soft scaffolding	292.423	292.423	4.759	0.037*	Holist > Serialist *
	Scaffolding	Serialist	1746.806	873.403	12.692	0.000***	Hard scaffolding > non-scaffolding *** Soft scaffolding > non-scaffolding **
		Holist	2073.205	1036.602	11.885	0.000***	Hard scaffolding > non-scaffolding ** Soft scaffolding > non-scaffolding ***
Learning efficiency	Cognitive style	Non-scaffolding	.036	.036	.014	0.906	
		Hard scaffolding	2.882	2.882	5.440	0.026*	Serialist > Holist *
		Soft scaffolding	6.028	6.028	8.000	0.008**	Holist > Serialist **
	Scaffolding	Serialist	7.889	3.944	2.464	0.096	
		Holist	12.105	6.052	5.990	0.005**	Hard scaffolding > non-scaffolding *** Soft scaffolding > non-scaffolding **
Overall learning performance	Cognitive style	Non-scaffolding	0.030	0.030	0.005	0.945	
		Hard scaffolding	2.210	2.210	3.525	0.023	Serialist > Holist *
		Soft scaffolding	9.329	9.329	8.907	0.006	Holist > Serialist **
	Scaffolding	Serialist	44.976	22.488	6.188	0.004*	Hard scaffolding > non-scaffolding **
		Holist	58.546	29.273	9.870	0.000***	Hard scaffolding > non-scaffolding ** Soft scaffolding > non-scaffolding ***

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

For any kind of cognitive styles, positive and overall learning emotion in hard scaffolding DGBL was significantly higher than those in non-scaffolding DGBL. In terms of Serialist cognitive style, negative learning emotion in hard scaffolding DGBL was significantly lower than that in soft scaffolding DGBL; negative learning emotion in soft scaffolding DGBL was significantly lower than that in non-scaffolding DGBL. As for Holist learning style, negative learning emotion in soft scaffolding DGBL was significantly lower than that in hard scaffolding DGBL; negative learning emotion in hard scaffolding DGBL was significantly lower than that in non-scaffolding DGBL. The above results were consistent with previous researches (Augustin, 2016; Beckmann et al., 2015; Huang et al., 2016), and corresponded to the cognitive-styles hypothesis of Pashler et al. (2009) and Kirschner (2017). Nevertheless, the difference was that these studies did not aim at scaffolding DGBL and elder adults, but regular

Table 9 The mean and standardized deviation of learning performance between scaffolding DGBLs and cognitive styles

Scaffolding DGBL	Cognitive style	Learning effect		Learning efficiency		Overall learning performance	
		M	SD	M	SD	M	SD
Non- scaffolding	Serialist	77.000 (77.458)	9.599 (2.081)	− 0.793 (− 0.611)	1.052 (.237)	− 0.784 (− 0.692)	0.900 (0.492)
	Holist	77.059 (76.973)	12.507 (1.954)	− 0.961 (− 1.269)	1.732 (.223)	− 0.779 (− 1.105)	1.173 (0.462)
Hard scaffolding	Serialist	91.053 (92.292)	7.696 (1.366)	0.664 (0.761)	0.758 (0.127)	0.958 (1.131)	1.414 (0.236)
	Holist	85.333 (85.804)	6.935 (1.585)	0.007 (− 0.081)	0.687 (0.148)	0.448 (0.340)	0.857 (0.274)
Soft scaffolding	Serialist	85.000 (85.774)	9.636 (1.965)	0.001 (0.045)	0.951 (0.197)	0.065 (0.012)	1.559 (0.379)
	Holist	92.186 (92.661)	9.656 (1.901)	0.894 (0.881)	0.782 (0.190)	1.160 (1.135)	1.529 (.367)

The data in parentheses was adjusted mean and adjusted standardized deviation

digital learning and the young instead. According to Saleh et al. (2022), to be successful in collaborative learning or soft scaffolding game, learners must be engaged in self-directed learning, that meets adults' characteristic. Thus, soft scaffolding DGBL is quite suitable to adults.

Extraneous cognitive load of Serialist learners was significantly lower than that of Holist learners in hard scaffolding DGBL, and germane cognitive load of Serialist learners was significantly higher than that of Holist learners as well; extraneous cognitive load and total cognitive load of Holist learners was significantly lower than those of Serialist learners in soft scaffolding DGBL, and germane cognitive load of Holist learners was significantly higher than that of Serialist learners as well. As for Serialist cognitive style, extraneous cognitive load in hard scaffolding DGBL was significantly lower than that in non-scaffolding DGBL, and germane cognitive load in hard scaffolding DGBL was significantly lower than that in non-scaffolding DGBL. Concerning Holist cognitive style, extraneous cognitive load and total cognitive load in soft scaffolding DGBL was significantly lower than those in non-scaffolding DGBL, and germane cognitive load in soft scaffolding DGBL was significantly lower than that in non-scaffolding DGBL. The above results were consistent with previous researches (Höffler & Schwartz, 2011), and corresponded to the cognitive-styles hypothesis of Pashler et al. (2009) and Kirschner (2017). The difference was these studies merely aimed at multimedia learning and the young rather than scaffolding DGBL and elder adults.

In hard scaffolding DGBL, learning effect, learning efficiency, and overall learning performance of Serialist learners were significantly better than those of Holist learners; however, in soft scaffolding DGBL, learning effect, learning efficiency, and overall learning performance of Holist learners were significantly better than those of Serialist learners. No matter what kind of cognitive styles, learning effect in soft and hard scaffolding DGBL were significantly better than that in non-scaffolding DGBL. Regarding Serialist cognitive style, learning effect and overall learning performance in hard scaffolding DGBL were better than those in non-scaffolding DGBL, and learning effect in soft scaffolding DGBL was better than that in non-scaffolding DGBL; nevertheless, learning efficiency in different scaffolding DGBL had no significant differences. As for Holist cognitive style, learning effect, learning efficiency, and overall learning performance in soft and hard scaffolding DGBL were significantly better than those in non-scaffolding DGBL.

As stated above, hard scaffolding was appropriate for Serialist learners, possibly because hard scaffolding system was linear and gradual in the DGBL material; therefore, learners had to learn step by step, which correspond with the traits of Serialist learners. As for the reason why soft scaffolding was suitable for Holist learners probably lies in the fact that they did not depend on linear hard scaffolding system, and preferred non-linear soft scaffolding system with online peer discussion.

The above results were consistent with other previous results (Chen & Chang, 2016; Clewley et al., 2011; Höffler & Schwartz, 2011), and the traits of soft and hard scaffolding (Saye & Brush, 2002), cognitive style theory (Lee et al., 2005; Thomas & McKay, 2010) and hypothesis (Kirschner, 2017; Pashler et al., 2009), and CATLM (Mayer, 2019). The differences were these studies aimed at neither scaffolding DGBL nor elder adults. Clewley et al. indicated, hard scaffolding was more suitable for Serialist learners, and soft scaffolding was more suitable for Holist learners; Chen and Chang only adopted soft scaffolding, collaborative learning, and they did not explore the impact of hard scaffolding and cognitive styles on learning performance. Höffler and Schwartz (2011) investigated the impacts of various multimedia learning environments and cognitive styles on learning performance. All the above studies neither explored learning efficiency nor aimed at elder adults. However, the confirmation of the assumed crossover interactions in the cognitive-styles hypothesis of Pashler et al. (2009) is not a proven fact, but rather a belief supported by little empirical evidence and week theoretical basis (Kirschner, 2017).

Previous research argues that older adults perceived themselves as having slightly less “load” than the young and middle-aged adults (Merriam et al., 2020). “Load” consists of internal load such as aspiration, desire, or expectation, and external load such as family, work, or community responsibility. Although Merriam’s “load” of adults is not identical to Sweller’s “cognitive load” in the study, it might affect adult learner needs, performance including cognitive load, and participation including emotion and motivation in learning and study (Merriam et al., 2020). Thence, the above results found in the study would be possibly influenced by Merriam’s “load” of adults.

Conclusion and implications

Summary

Several key points of results were summarized as follows: (1) There were no significant differences on learning emotion, cognitive load, and learning performance among various cognitive styles, but in soft or hard scaffolding DGBL, whereas there were significant differences on learning emotion, cognitive load, and learning performance among various cognitive styles. (2) In hard scaffolding DGBL, learning emotion, cognitive load, and learning performance of Serialist learners were significantly better than those of Holist learners. Conversely, in soft scaffolding DGBL, learning emotion, cognitive load, and learning performance of Holist learners were significantly better than those of Serialist learners. (3) Positive learning emotion, overall learning emotion, germane cognitive load, learning effect, and overall learning performance of Serialist learners using hard scaffolding DGBL were significantly better than those of learners using non-scaffolding DGBL, while negative learning emotion and extraneous cognitive load were significantly lower. Only negative learning emotion, total cognitive load, and learning efficiency had no significant differences. (4) Positive learning emotion, overall learning emotion, germane cognitive load, learning effect, learning efficiency, and overall learning performance of Holist learners using soft scaffolding DGBL were significantly better than those of learners using non-scaffolding DGBL, while negative learning emotion, extraneous cognitive load, and total cognitive load were significantly lower. Perhaps these findings above could be resulted from the age of the learners; however, they cannot be further identified, since there are no sufficient previous studies on emotion and cognitive load of elder adults using DGBL or other technologies.

Contributions

The contributions of this study include practically: 1. the significantly interactive effects of scaffolding DGBL and cognitive styles on learning emotion, cognitive load, and learning performance are confirmed, and better combinations of scaffolding and cognitive styles for learning are found; 2. suggesting instructors and DGBL designers regarding applying various scaffolding and cognitive styles on DGBL. Theoretically, this study ensures sufficiency of applying CATLM, cognitive load theory and cognitive style theory on DGBL, suggesting to extend the application of these theories to scaffolding.

Implications

In soft or hard scaffolding DGBL, learning emotion, cognitive load, and learning performance of various learners' cognitive styles had significant differences. Thus, when instructors design and apply scaffolding DGBL, they should not only consider scaffolding themselves, but also learners' cognitive styles. In this way, scaffolding or learning guidance could be designed to conform to learners' traits, and their learning performance could be more effectively enhanced.

Learners with different cognitive styles would generally attain contrary results on their learning emotion, cognitive load, and learning performance in soft or hard scaffolding DGBL. Therefore, when applying different scaffolding DGBL, the disturbance of cognitive styles should be taken into consideration. In other words, learners with different cognitive styles should be allowed to choose suitable scaffolding DGBL for themselves in order to enhance the adaptable learning effect. In soft or hard scaffolding DGBL, learning emotion, cognitive load, and learning performance of Serialist and Holist learners were approximately on the contrary. Hence, learners with different cognitive styles should choose suitable scaffolding DGBL to enhance the adaptable learning effect.

Soft scaffolding was more suitable for Holist learners than that for Serialist learners; hard scaffolding was more suitable for Serialist learners than that for Holist learners. Comparing to non-scaffolding, Holist learners using soft scaffolding performed the best, and Serialist learners using hard scaffolding were the second. Thus, instructors could firstly guide Holist learners to use hard scaffolding, and then Serialist learners to use soft scaffolding; in this way, learning performance would be well-improved.

Limitations

With middle and high-aged adult subjects, the findings in the study turn into important references to discuss their emotion and cognitive load as well as support or intervene their performance when using DGBL. However, there are no sufficient literatures from previous studies on emotion and cognitive load of elder adults to further confirm the rationale behind the findings for them. One limitation of the study is that the results of the study cannot be generalized to other subjects. In the future, learners of different age groups can be investigated in order to obtain various results. Furthermore, the findings in the study would be possibly influenced by Merriam's "load" of adults (see section Discussion). However, how they are influenced for adults remains unknown. Comparison of the outcomes found in the study between different aging groups could be further investigated. This study adopted hard/soft scaffolding and Holist/Serialist cognitive styles; in the future, the impact of other types of scaffolding and cognitive styles on DGBL can be explored.

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Author contributions
C-CC made substantial contributions to conceptualization, formal analysis, methodology, project administration, resources, supervision, validation, writing—original draft and critical revision, writing—review & editing. S-TY made substantial contributions to conceptualization, software, data acquisition and curation, data analysis and interpretation, investigation, methodology, validation, visualization, writing—original draft. Both authors read and approved the final manuscript.

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