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Remote Blended Game-Based Learning: Integrating Synchronous Game-Based Learning with Asynchronous Inquiry-Based Learning

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Abstract
The COVID-19 pandemic has drawn the attention of educators to the blended learning model. This study developed a remote blended game-based learning activity that integrates digital game–based learning (DGBL) and blended learning (including online synchronous and asynchronous learning). This method emphasizes that in the online synchronous learning activity, students firstly use mini-educational digital games for group collaborative autonomous pre-learning and then take part in a problem-solving discussion activity guided by the teacher. Afterwards, students complete personal inquiry learning tasks in the asynchronous online activity and conduct asynchronous discussions. This study employed a quasi-experimental design. Participants were 73 senior high school students. The first group used the remote blended game-based learning that integrated DGBL into online synchronous learning. The second group used the face-to-face blended game-based learning approach that integrated DGBL into physical classroom learning. The third group used the remote blended video-based learning that integrated online synchronous video-based learning. The three groups conducted the same online asynchronous inquiry learning tasks. The results found that the remote blended game-based learning activity not only significantly promoted the students' learning performance in online synchronous learning but also supported their learning performance in online asynchronous learning. Besides, most students' discussion messages were mostly related to the learning tasks and topic.

Keywords Blended learning · Synchronous · Asynchronous · Digital game–based learning · Collaborative learning

Introduction

In response to COVID-19, distance learning instantly became a topic of concern for educational researchers in recent years (Cesco et al., 2021; Doll et al., 2021). Although distance learning minimized the impact on students' learning progress in school during the epidemic and allowed teachers and students at different times and in different locations to attend classes by using online synchronous and asynchronous learning, the lack of student–student, student–teacher, and student-content interactions (Baber, 2021) often made students feel isolated (Heringer, 2022), and their engagement (Flynn et al., 2021), concentration (Friedman, 2020), and learning performance (Walters et al., 2022) were all significantly reduced during distance learning.

Interaction is the important fundamental for distance learning (Farmer & West, 2019). Researchers recommend using the function of breakout rooms in synchronous videoconferencing, or using asynchronous discussion forums to facilitate student engagement through discussion activities between teachers and students and between students (Liao et al., 2021). However, discussion activities faced some challenges, such as the limited number of discussion messages (Hou et al., 2015b), students' lack of concentration and in-depth discussion (Lin et al., 2014) in the discussion process, and whether the discussion content is relevant to the learning topic (Maimaiti et al., 2021).

In this condition, using only synchronous or asynchronous methods is not sufficient to support distance learning for students. Instead, a blended learning approach is required (Moorhouse & Wong, 2022). Shamir-Inbal and Blau (2021) indicated that teachers can use a blended learning model, such as blended learning that integrates online synchronous and asynchronous learning (Ng et al., 2020) to respond to above limitation for distance learning.

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Concerning the teaching materials of blending learning, many teachers often use pre-recorded instructor lectures to allow students to learn in online synchronous or asynchronous learning (Lowenthal et al., 2020; Malkin et al., 2018). However, videos are a one-way teaching mode without interaction; students might feel this method is boring (Zainuddin & Attaran, 2016). The length of videos has also affect students' motivation and concentration to watch (Karabulut-Ilgu et al., 2018). Even if all students watch the teaching video together in synchronous videoconferencing, there will be no autonomous learning behavior (Choi & Yang, 2011). Moreover, teachers cannot be sure whether students have watched the video or not completely and attentively (Förster et al., 2022).

Researchers have suggested that teachers can apply digital games to distance learning activities and use the feature of highly interactive and collaborative games to address the limitations and deficiencies of distance learning (Chang et al., 2022; Tang et al., 2021). A few studies have explored the effectiveness of digital games in online synchronous or asynchronous learning (Krouska et al., 2022; McLaren et al., 2022). However, most of these studies did not conduct an empirical analysis (Alonso & Schroeder, 2020; Manzano-León et al., 2021) or lacked the proposal of a teaching practice framework that combines digital games with blended learning. Therefore, to fill the gaps in the research, this study aimed to develop a blended learning model—"remote blended game-based learning activity" that applied digital games to online synchronous learning and integrated asynchronous inquiry learning, and evaluated its impact on teaching practice.

Besides the blended learning model that integrates online synchronous and asynchronous learning, integrating face-to-face instruction and online asynchronous learning is the most common blended learning model at the present time (Zagouras et al., 2022). Although numerous studies have found that DGBL can promote students to learn in the physical classroom (Tsai & Tsai, 2020), there is a lack of research to further investigate the overall impact of digital games on blended learning model that integrates face-to-face instruction and online asynchronous learning. Furthermore, teaching videos are commonly used in a blending learning model that integrates online synchronous and asynchronous learning (Maimaiti et al., 2021).

Therefore, in addition to the remote blended game-based learning activity mainly proposed in this study, we also proposed two other blended learning methods based on the above points: a face-to-face blended game-based learning activity that integrates digital game–based learning into physical classroom and online asynchronous individual inquiry learning tasks and a remote blended video-based learning activity that integrates online synchronous video-based learning and online asynchronous personal inquiry learning tasks. This study conducted empirical analysis with the topic of science education to examine the effectiveness of these three proposed methods. The research questions are as follows:

1. In online synchronous activities, what are the differences in students' learning performance using these three blended learning methods?
2. In online synchronous activities, what are the differences in students' discussion concentration using these three blended learning methods?
3. In online asynchronous activities, what are the differences in students' learning performance using these three blended learning methods?
4. In online asynchronous activities, what are the differences in students' discussion concentration using these three blended learning methods?

Literature Review

Blended Learning

A common definition of blended learning is the integration of traditional face-to-face instruction and online learning, where the online learning may be either online synchronous or asynchronous learning (Brown, 2016). With the development of information technology, the definition of blended learning has also been expanded, including being defined as a learning form that integrates online synchronous and asynchronous learning (Heilporn et al., 2021).

For online synchronous learning, teachers and students could conduct online learning activities for teaching–learning topics in different places at the same time via videoconferencing tools such as the Zoom or Google Meet applications (Weiser et al., 2018). Furthermore, breakout rooms can be used to give students learning tasks to engage them in collaborative discussion activities so as to facilitate their interaction (Krishnan et al., 2018). For online asynchronous learning, teachers could upload teaching videos, materials, and homework to the learning management system (LMS) (e.g., Google Classroom, Moodle) for students to learn independently (Mankki, 2022). Besides, the utilization of asynchronous discussion forums allows them to discuss difficult or complex learning topics (Yamagata-Lynch, 2014). Researchers have claimed that blended learning can integrate the benefits of online synchronous and asynchronous learning and achieve complementary effects (Moorhouse & Wong, 2022; Shamir-Inbal & Blau, 2021).

While consensus is emerging on the benefits of blended learning, research findings on its effectiveness remain inconclusive (Ma & Lee, 2021). Some research has found that blended learning is more effective than face-to-face

instruction (Müller & Mildenberger, 2021). Some research has shown that students prefer face-to-face instruction over online synchronous, asynchronous, or blended learning combining the two (Garbe et al., 2020). Moreover, researchers have also reported that there was no significant difference in the learning effect of blended learning, face-to-face instruction, and pure online learning methods (Kumar et al., 2019).

Students' motivation and engagement have been identified as key factors in the success of distance learning (Aguilera-Hermida, 2020; Wong et al., 2020). Researchers have indicated that teachers can integrate digital games into distance learning activities and take advantage of the highly interactive and collaborative nature of games to facilitate student learning (Ng et al., 2020; Tang et al., 2021).

DGBL and Blended Learning

Digital game–based learning (DGBL) has been widely discussed by researchers in the field of education (Bado, 2022). DGBL can effectively promote students' learning motivation and learning performance (Hussein et al., 2022; Wang et al., 2022), as well as improve their discussion concentration (Li et al., 2022).

To date, a few researchers have investigated the effects of digital games on students' learning in online synchronous or asynchronous learning environments. For instance, Chang et al. (2022) employed the Gather.town platform to develop an online game learning system for online asynchronous nursing courses. The results indicated that the approach improved student achievement and learning engagement more than using video-based instruction did. Manzano-León et al. (2021) used an online escape room game as a motivational strategy in an online synchronous activity. The results of their qualitative research showed that students believed this approach to be interesting and useful. Zhyhadlo (2022) adopted Wordwall and Kahoot in an online synchronous activity for foreign language courses and reported that it promoted students' learning effectiveness and motivation. The research results of Velaora et al. (2022) noted that integrating digital games into distance learning activities can motivate students to learn and can positively affect their attention, confidence, and satisfaction.

Although the above studies have confirmed the benefits of digital games in the distance learning field, there are also studies that have reported negative effects. McLaren et al. (2022) pointed out that the rate of students completing game learning autonomously in online asynchronous learning activities was low (56.5%). Students also felt that using games for learning during online synchronous learning activities caused them pressure (Manzano-León et al., 2021). In addition, some studies did not conduct empirical research (Alonso & Schroeder, 2020; Vergne et al., 2020) or did not propose a specific framework for teaching practice (Doğantan, 2020; Zhyhadlo, 2022). Most studies only analyzed the effects of digital games in online synchronous or asynchronous learning environments (Chang et al., 2022; Manzano-León et al., 2021), without further evaluating the overall impact of blended learning, and lacked a more multidimensional analysis such as separately discussing learners' concentration in online synchronous and asynchronous learning environments. Therefore, it is necessary to explore the effectiveness of using digital games in the blended learning mode to fill the gaps in the relevant research.

Remote Blended Game-Based Learning

bBased on the framework of the mini-game-based flipped classroom (Li et al., 2022), a remote blended game-based learning activity that integrates digital game–based learning and blended learning (including online synchronous and asynchronous learning) was proposed in this study. The framework is explained as follows (Fig. 1).

The First Stage: The Online Synchronous Digital Game–Based Learning Activity

This stage consists of two parts: the online synchronous digital game–based autonomous pre-learning activity and the online synchronous problem-solving discussion activity guided by the teacher.

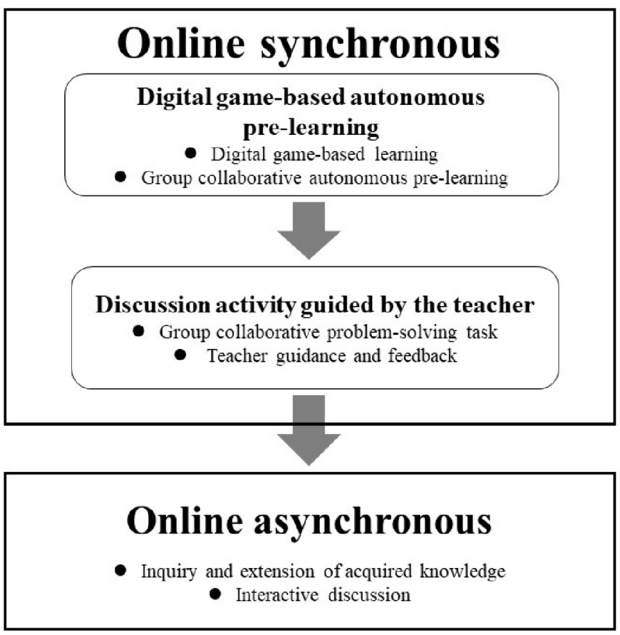

Fig. 1 The framework of the remote blended game-based learning activity

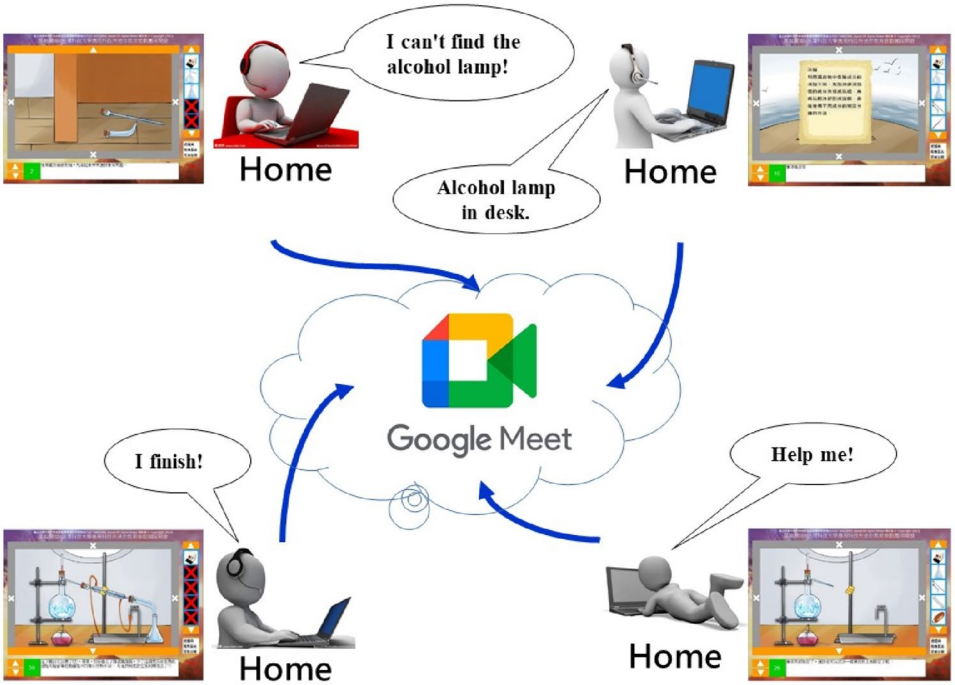

Fig. 2 The situation of the online synchronous digital game–based autonomous pre-learning activity

Online Synchronous Digital Game–Based Autonomous Pre-learning Activity

The teacher gives students 20–30 min to operate the mini-educational digital games on their desktop computer/laptop for group autonomous pre-learning at the beginning of the course, and students complete the game challenge tasks in the process of group collaborative discussion through videoconferencing tools (e.g., Google Meet). In other words, students firstly use the games for group collaborative autonomous pre-learning in breakout rooms in the early stage of the class, and the learning materials are the 5–20 min mini-educational digital games with contextual and challenging tasks. The situation of learning is shown in Fig. 2.

Online Synchronous Problem-Solving Discussion Activity Guided by the Teacher

After the digital game–based autonomous pre-learning activity, the teacher guides the whole class to engage in problem-solving discussion of the learning content knowledge. Students are guided to review the cognitions established in the game-based autonomous pre-learning activities. Note that proper guidance and immediate feedback are given to help students learn correctly. The situation of learning is shown in Fig. 3.

The online synchronous digital game–based learning activity proposed in this study emphasizes the use of videoconferencing tools to build the digital game–based learning activities that were originally implemented in physical classrooms in the online synchronous learning environment. Firstly, the 5–20-min mini-educational digital game is applied to excite students' autonomous learning motivation and elementary collaborative discussion. Then, the student-centered problem-solving discussion activities guided by the teacher aim to increase the students' concentration and reduce their anxieties. These activities were completed by the teacher and students within the course time, and so did not affect the teaching progress.

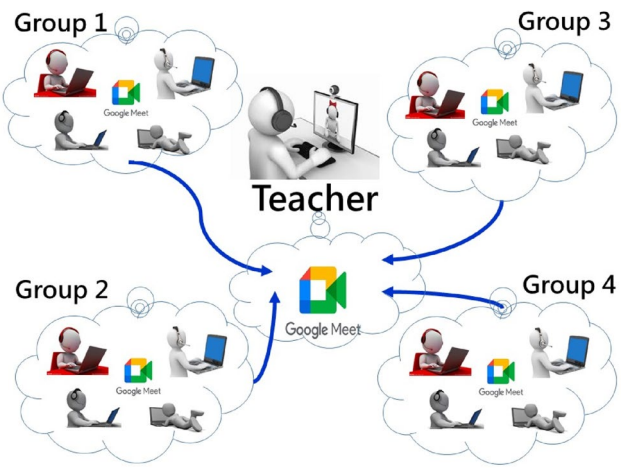

Fig. 3 The situation of the online synchronous problem-solving discussion activity guided by the teacher

The Second Stage: Online Asynchronous Inquiry-Based Learning Activity

In the online asynchronous inquiry-based learning activity for individual students, students are given an inquiry task related to the learning and game topic and are allowed to use the Internet to search for and interpret information. They then publish their personal answers to the inquiry task on the LMS (e.g., Google Classroom) of the class. Additionally, students are free to engage in interactive discussions on the forum. This activity aimed to enhance and extend individual students' intrinsic motivation and expand the knowledge content acquired by students in the online synchronous digital game–based learning activity. Meanwhile, it was expected that it would further develop their high-level cognitive thinking and problem-solving abilities.

Method

Participants

The study had an experiment with a quasi-experimental design and adopted purposive sampling to reflect on the real teaching practice. This experiment was implemented in a senior high school chemistry course. Participants were 73 students from three classes of tenth graders in northern Taiwan. The school chemistry courses of these three classes were taught by the same teacher. This teacher was the instructor in this study. The participants' informed consent has been obtained before the experiment began.

The three classes were randomly assigned to three different experimental groups. One class was the first experimental group ($n=27$; 19 males, 8 females), who learned with the remote blended game-based learning method (the RBGL group). Another class was the second experimental group ($n=23$; 14 males, 9 females), who learned with the face-to-face blended game-based learning method (the F2FBGL group). The other class was the third experimental group ($n=23$; 10 males, 13 females), who learned with the remote blended video-based learning method (the RBVL group).

Experimental Design

A stand-alone mini-educational digital escape room game "Distillation©" (Hou et al., 2015a) was used in this study. The game learning goals were understanding of the knowledge related to distillation experiments. Students needed to collect chemistry experiment tools in the process of game exploration and had to follow the correct distillation procedure to correctly make a distillation device. A video of a chemistry distillation experiment was the teaching material that was produced by a chemistry teacher for this study. The learning content of this video and game was consistent.

The RBGL group and the F2FBGL group used "Distillation©" to conduct the autonomous pre-learning activity in the online synchronous and physical classroom environment, respectively. The RBVL group watched the teaching video in the online synchronous autonomous pre-learning activity. The LMS of the online asynchronous inquiry-based learning activity adopted Google Classroom. Before beginning the online asynchronous learning activity, the teacher introduced and demonstrated the operation of Google Classroom. For high school students, Google Classroom is already a very familiar tool. The three groups both adopted the same inquiry task, and the instruction was "Please find a substance that is produced by distillation in real life, and explain the production method and its relevance to distillation." Students in each of the three groups were grouped into teams of three to four members. The experimental design is shown in Fig. 4.

Instruments

The instruments included the learning performance test and recording of students' discussion content of the synchronous (online/physical classroom) learning activity, learning performance of online asynchronous personal inquiry task, and discussion content of Google Classroom.

To explore the learning performance in the synchronous activity of the three groups, the pre- and post-tests based on teaching goals in this study were developed by the teacher of the current study and a professor for expert validity. The pre- and post-tests adopted the same questions. The test included the knowledge of chemistry distillation experiment and the order of the distillation experiment. There were 24 blank-filling questions, three multiple choice questions, and four essay questions, with a perfect score of 100. The pre-test aimed to examine the students' prior knowledge of the distillation experiment, and the post-test aimed to evaluate the students' learning performance after the synchronous learning activity.

To explore the discussion concentration in the synchronous activity of the three groups, the study used a voice recorder to record the students' peer-communication content in the first stage, including students playing the game or watching the video and having discussions guided by the teacher (55 min in total). To better present the context and interaction of students' communication content, we transcribed this communication content based on one completed message as one encoding unit for later analysis. There were 3075, 5979, and 1854 messages from the RBGL, F2FBGL, and RBVL groups, respectively.

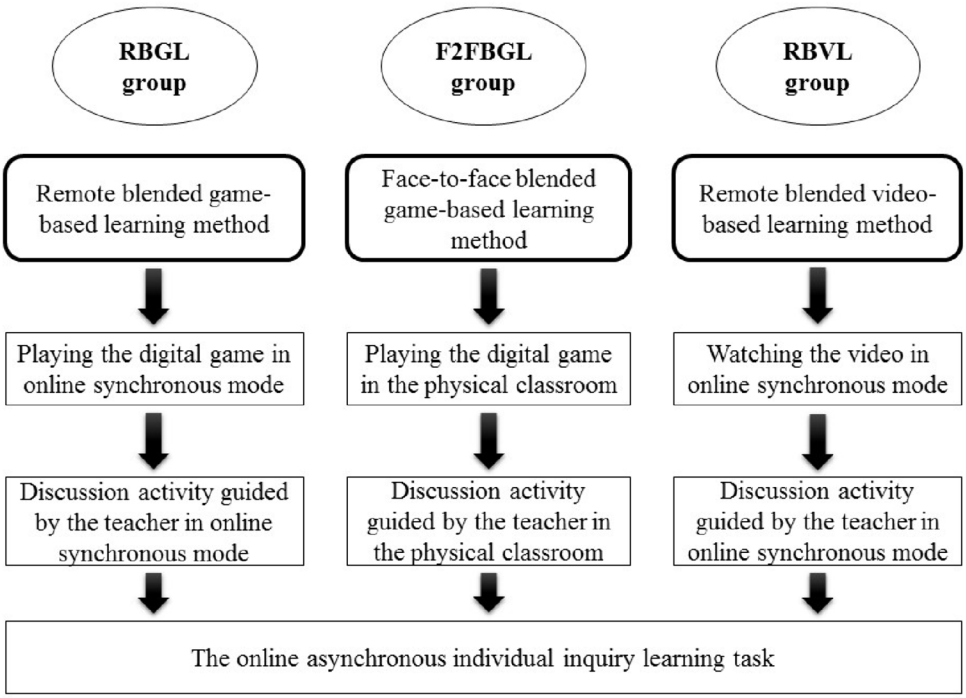

Fig. 4 The experimental design

To explore the learning performance of the online asynchronous inquiry task of the three groups for individual students, this study referred to pervious research of distance learning (Calderon & Sood, 2020; Jorczak, 2014; Vonderwell et al., 2007) to identify three assessment criteria: accuracy (the answer is for the task), validity (the answer is correct), and completeness (the answer is complete). The teacher scored the answer submitted by students in Google Classroom according to these three dimensions. Each dimension was scored on a scale of 1–5, with a perfect score of 15. The sum of scores of the three dimensions was the student's learning performance in the online asynchronous inquiry-based learning activity.

To explore the discussion concentration in the asynchronous activity of the three groups, we collected the comments posted by the three groups of students in Google Classroom. One comment means one encoding unit. We coded single comment units posted by each student. There were 34, 81, and 54 comments from the RBGL, F2FBGL, and RBVL groups, respectively.

Quantitative Content Analysis

The study adopted quantitative content analysis (QCA) to analyze the recorded data in the synchronous activity and the comments posted in Google Classroom to explore the students' concentration on discussions. QCA is a research technique that can display the quantitative description of the manifest content of communication (Berelson, 1952). It is a systematic procedure that firstly segments the communication content into units, assigns each unit to a category, then counts numbers for each category (Rourke & Anderson, 2004). QCA is commonly used to analyze students' discussion content in the learning process, such as the concentration on discussion and discussion patterns, and has been widely used in previous studies (e.g., Chou et al., 2023; Zheng et al., 2020). Based on Li et al. (2022), the coding scheme of concentration on discussion in this study was developed.

Table 1 The coding scheme of concentration on synchronous discussion

Categories	Example
On-topic	"A thermometer is used to measure the change in temperature of the solution," "I can't find the alcohol lamp in the game."
Off-topic	"Let's play the online game," "I'm so glad I don't have to go to school because of COVID-19"

Table 2 The coding scheme of concentration on online asynchronous discussion

Categories	Example
NQ-on-topic	"What is ABV?"
RQ-on-topic	"ABV is alcohol by volume."
IR-off-topic	"The joke you posted is hilarious."

NQ-on-topic new question related to the topic, *RQ-on-topic* response to other people's question related to the topic, *IR-off-topic* deviation from the learning topic

The Concentration on Synchronous Discussion

Before the coding, two researchers with encoding experience set each single message as the analysis unit to define the encoding categories included "on-topic message" and "off-topic message." The coding scheme is shown in Table 1.

To ensure the encoding consistency of the two researchers, one RBGL group (442 messages), one F2FBGL group (1,029 messages), and one RBVL group (290 messages) were randomly chosen for the researchers to encode. The inter-rater kappa coefficient was 0.782 which showed that the coding results had good consistency between the researchers.

The Concentration on Online Asynchronous Discussion

Before the coding, two researchers set each single comment posted by a student as the analysis unit to define the encoding categories which included "new questions related to the learning topic (NQ-on-topic)," "response to other people's questions related to the learning topic (RQ-on-topic)," and "comments irrelevant to the learning topic (IR-off-topic)." The coding scheme is shown in Table 2. Due to the small number, a total of 169 comments in three groups were discussed by two researchers for consensus coding. Therefore, coding consistency of all comments was the consensus of the researchers.

Experimental Procedure

Students first filled out the informed consent document and took the pre-test (20 min) before the experiment. After the first stage of the synchronous learning activity (55 min) was completed, students took the post-test (20 min). Next, the teacher announced the subject of the online asynchronous inquiry task, explained how the activity would be conducted, and demonstrated how to operate Google Classroom (10 min).

After the end of the first stage of the synchronous learning activity, the second stage of the online asynchronous inquiry-based learning activity for individual students started. The students needed to publish the answers to the inquiry task on Google Classroom within 1 week. In addition, they were required to ask questions about at least one of their classmates' published answer and answer questions from other students in Google Classroom. The experiment procedure is shown in Fig. 5.

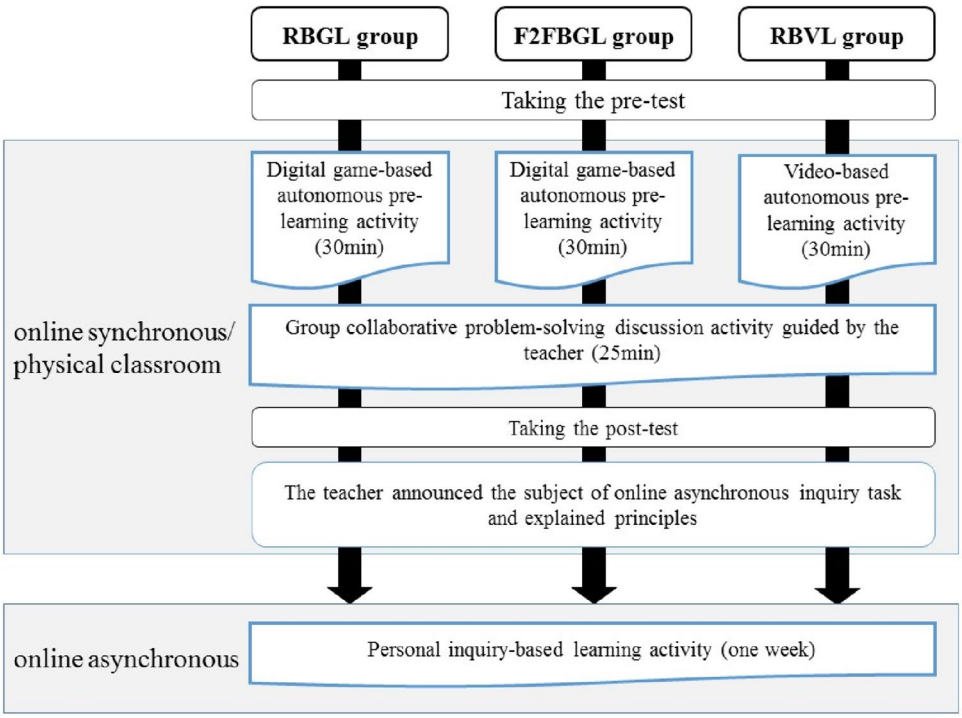

Fig. 5 The experiment procedure

Table 3 The ANCOVA result of the three groups' learning performance in the synchronous learning environment

Group	Mean	*S.D*	Adj.*M*	S. Err	*F*	Post hoc
RBGL	67.70	14.71	66.21	2.12	48.295***	RBGL > RBVL F2FBGL > RBVL
F2FBGL	65.65	9.75	65.19	2.26		
RBVL	35.61	10.39	37.82	2.32		

***$p < .001$

Results

Analysis of Learning Performance of Synchronous

The study employed an analysis of covariance (ANCOVA) to evaluate the difference of students' learning performance in the synchronous learning activities of the three groups. The pre-test was used as a covariate, and the post-test was used as a dependent variable. The assumption of homogeneity regression was satisfied for the pre-test ($F = 1.160$, $p = 0.320 > 0.05$), indicating that the ANCOVA could be applied to compare the difference of students' post-test.

The ANCOVA results are shown in Table 3. There was a significant difference between the three groups on the post-tests ($F = 48.295$, $p < 0.001$), showing students' post-test varies from the learning method. The post hoc analysis must be performed to determine which groups differ from each other. The results of post hoc analysis found that the post-tests of the RBGL group were significantly better than those of the RBVL group. In addition, the post-tests of the F2FBGL group were also significantly better than those of the RBVL group. These finding suggested that in the first stage of the synchronous learning activity, whether students learned with DGBL in online or physical classroom environments, their learning performance in the chemical distillation experiment was better than that of those students who learned by watching teaching videos in the online synchronous learning environment.

Analysis of Discussion Concentration in the Synchronous Learning Environment

The study conducted the chi-squared test to evaluate the correlation of the percentage distributions between the two categories of the on-topic and off-topic. As shown in Table 4, there was a significant difference between these three groups ($\chi^2 = 26.616$, $p < 0.001$). The post hoc analysis must be performed to determine which groups differ from each other. The results showed that the on-topic percentage of the RBGL group was significantly higher than that of the F2FBGL group (72.6% > 67.4%). Furthermore, the off-topic percentage of the RBGL group was significantly lower than that of the F2FBGL group (27.4% < 32.6%).

The above results suggest that students in the RBGL group created a higher proportion of discussion messages related to the learning topics and a lower proportion of discussion messages unrelated to the learning topics than students in the F2FBGL group. This finding implies that students who learned with DGBL in the online learning environment showed better-quality concentration on discussion in the synchronous learning activity.

Table 4 The chi-squared test result of concentration on synchronous discussion of the three groups

Categories		Group			χ^2
		RBGL	F2FBGL	RBVL	
On-topic	Number	2231	4027	1301	26.616***
	Percent	72.6%	67.4%	70.2%	
Off-topic	Number	844	1952	553	
	Percent	27.4%	32.6%	29.8%	

***$p < .001$

Analysis of Learning Performance in the Online Asynchronous Environment

After the online asynchronous inquiry-based learning activity was completed, all students in the three groups had published their answers to the task to Google Classroom within the deadline. A one-way independent measure ANOVA was performed to examine differences in the learning performance of the online asynchronous activity of the three groups for individual students. The test of homogeneity variance did not violate the assumption ($F = 3.042$, $p = 0.054 > 0.05$), showing the variance of the three group was not significant difference. As shown in Table 5, the ANOVA results indicated that the learning performance of the online asynchronous activity showed no significant difference between the three groups ($F = 2.756$, $p > 0.05$). This result suggested that the three groups of students had equivalent learning performance of the online asynchronous inquiry task after the first stage of the synchronous learning activity.

Table 5 The ANCOVA result of learning performance of the online asynchronous activity by the three groups

Group	Mean	S.D	*F* value
RBGL	10.44	4.02	2.756
F2FBGL	9.83	1.40	
RBVL	8.35	3.39	

Table 6 The chi-squared test result of concentration on the asynchronous discussion of the three groups

Categories		Group			χ^2
		RBGL	F2FBGL	RBVL	
NQ-on-topic	Number	13	16	2	20.336***
	Percent	38.2%	19.8%	3.7%	
RQ-on-topic	Number	3	2	2	
	Percent	8.8%	2.5%	3.7%	
IR-off-topic	Number	18	63	50	
	Percent	53%	77.7%	92.6%	

***$p < .001$

Analysis of Discussion Concentration in the Online Asynchronous Environment

The chi-squared test was employed to evaluate the different of the percentage distributions of comments of the three categories. As shown in Table 6, there was a significant difference between these three groups ($\chi^2 = 20.336$, $p < 0.001$). The post hoc analysis must be performed to determine which groups differ from each other. The results found that the percentage of NQ-on-topic of the RBGL (38.2% > 3.7%) and the F2FBGL group (19.8% > 3.7%) was significantly higher than that of the RBVL group, respectively. However, there was no significant difference in the percentage of RQ-on-topic between the three groups. Moreover, for the percentage of IR-off-topic, the RBGL group was significantly lower than the F2FBGL group (53% < 77.7%) and was also significantly lower than the RBVL group (53% < 92.6%).

Although the percentage of category of response to other people's questions related to the learning topic showed no significant difference between the three groups, the above results still show that students who learned with DGBL could create a greater proportion of new questions related to the learning topic and a lower proportion of comments unrelated to the learning topics. Therefore, these findings imply that the RBGL group students had better-quality concentration on discussion in the second stage of the asynchronous discussion activity.

Despite reaching the above conclusions through statistical analysis, the proportion of IR-off-topic comments of the three groups was on the high side (all higher than 50%). In addition, the proportion of the two categories related to the learning topic (NQ-on-topic and RQ-on-topic) of the three groups was on the low side, with few such comments. We will discuss this phenomenon in the next section.

Discussion

This study developed a remote blended game-based learning activity whereby in the synchronous online learning activity of the first stage, students firstly used the mini-educational digital games for group collaborative autonomous pre-learning and then took part in the problem-solving discussion activities guided by the teacher. Afterwards, students completed personal learning tasks in the asynchronous online activity of the second stage and conducted asynchronous discussions. The research results were organized as shown in Table 7.

Regarding the learning performance in the synchronous activity, numerous studies have pointed out that DGBL is an effective way to facilitate student learning (e.g., Hussein et al., 2022; Wang et al., 2022). Digital games can provide an interesting learning environment that allows students to fully engage in, focus on and enjoy acquiring knowledge (Hwang et al., 2015). Additionally, the games of collaborative problem-solving tasks improve interaction and knowledge sharing among group members (Chou et al., 2023). The results of this study indicated that adopting DGBL in an online synchronous learning environment can also effectively promote students' learning performance. Students' learning performance in the DGBL activities will not be affected by the transition from a face-to-face classroom to the online synchronous learning environment.

Regarding the learning performance in the asynchronous activity, the purpose of the online asynchronous inquiry learning tasks was to assist students in extending and expanding their understanding of the learning topics (Moorhouse & Beaumont, 2020) and to develop their ability of autonomous learning (Mankki, 2022). The results of this study suggested that the learning performance in the asynchronous activity using the remote blended game-based learning method was as good as in the other two blended learning methods (Zagouras et al., 2022). Previous studies in the field of blended learning have failed to separately

Table 7 Comparison of the research results of the three groups

Questions	Dimensions	Results
Q1	Learning performance in the synchronous activity	RBGL > RBVL F2FBGL > RBVL
Q2	Discussion concentration in the synchronous activity	RBGL > F2FBGL
Q3	Learning performance in the asynchronous activity	RBGL = F2FBGL = RBVL
Q4	Discussion concentration in the asynchronous activity	RBGL > RBVL

examine the learning performance of students in synchronous and asynchronous learning (Andujar & Nadif, 2022; Ma & Lee, 2021; Wong et al., 2020). Our study filled this research gap in this field.

Regarding the discussion concentration in the synchronous activity, the face-to-face learning environment can create more discussion messages. However, the language environment of fast and direct communication can also confuse the messages and produce ineffective dialogue (Hrastinski, 2010; Petty & Farinde, 2013). Therefore, this may be the reason why the F2FBGL group students had less concentration on discussion, although they had the most messages. On the other hand, due to the lack of face-to-face interaction in the online synchronous learning environment, students often turn off the microphone. Besides, in order to maintain the quality of the videoconferencing room, teachers also often ask students to turn off their microphones. Students may turn on the microphone to speak only when necessary. These factors will directly affect the occurrence of students' discussion behavior (whether it is on-topic or off-topic messages) (Dietrich et al., 2020). Thus, although the total number of discussion messages of the RBGL group students was less than that of the F2FBGL group, the discussion concentration in the synchronous activity was better. Previous studies have reported that students have digressive discussions in teaching activities (Li et al., 2022; Maimaiti et al., 2021). The results of this study suggest that teachers should give students discussion tasks, reflection activities, or collaborative tasks (Doll et al., 2021) and provide scaffolding and guidance to help students focus on the learning topics (Hou & Keng, 2021).

Regarding the discussion concentration in the asynchronous activity, the duration of the asynchronous discussion activity in this study was 1 week; we think it was appropriate and could match the school's curriculum progress. Besides, the asynchronous forums allowed students to engage in asynchronous interactive discussions anytime, anywhere (Shamir-Inbal & Blau, 2021). However, because the high school students needed to give consideration to other course at the same time, they did not have enough time for or were reluctant to spend too much time on interaction in the asynchronous discussion activities (Osborne et al., 2018). Considering the above factors, we believe that the number of asynchronous discussion comments presented by the three groups of students was within an acceptable range in this study. On the other hand, we conducted an informal interview with the three groups of students by the teacher after the learning activity. Most of the students said "I didn't know what to ask." When students ask fewer questions, the response behavior will be less. Asking and responding are a higher cognitive level (Newman et al., 1997), which can be difficult for students (Heo et al., 2010). Previous studies have indicated that students mainly shared knowledge in online asynchronous discussion activities and had fewer discussion behaviors of higher-order cognitive thinking or knowledge construction (Wang et al., 2017). Our research also found such results. The study of discussion activity design only allowed students to conduct autonomous asynchronous discussions in the online asynchronous learning, without teacher intervention or implementation of guiding strategies. Consequently, it may be difficult to improve students' high-level cognitive thinking or knowledge construction behavior during the discussion process (Hou, 2012).

Conclusions and Suggestions

In conclusion, our findings suggest that the use of digital games, when combined with blended learning, is an effective method for supporting student learning in the distance learning context. This study has two practical teaching implications. First, it is feasible to conduct DGBL in online synchronous learning. We encourage teachers to attempt to use well-designed mini-educational digital games in their online synchronous learning activities as part of blended learning. To utilize the high interactivity of the digital games, teachers may employ the breakout rooms in the videoconferencing tools to establish an online group collaborative learning environment. In the meantime, they can let students work together on problem-solving game tasks to arouse their motivation and promote their learning participation. When games allow students to engage in more interaction and discussion about learning, they can obtain more knowledge and enhance their learning (Sung & Hwang, 2018). Furthermore, teachers provide students with instant feedback and guidance, which is very important for students in online synchronous learning. Second, in the blended learning model, the online synchronous and asynchronous learning activities should be designed with coherence and consistency (Heilporn et al., 2021). The online synchronous digital game–based learning activity can extend students' learning motivation to online asynchronous inquiry-based learning activities. Most of the students could independently complete the online asynchronous inquiry tasks designed for this study and thus could expand their knowledge and understanding of the learning topics.

This study also has some limitations that should be noted. Firstly, long-term teaching research can further verify the effectiveness of the remote blended game-based learning method. Next, we focused on concentration on discussion rather than on learning behavior. We believe that although the RBGL group showed better discussion concentration, it does not mean that students are always concentrating on their studies. When a student turns off the microphone in online synchronous learning, teachers cannot confirm whether they are concentrating on learning or are distracted and exhibiting inattentive behavior. For example, students may open another window to play online games or watch YouTube at the same time on their computer (Octaberlina & Muslimin, 2020) or even leave their seat and the computer.

On the other hand, we suggest that students' computer operation behaviors can be recorded in the future, using QCA and sequence analysis to explore the learning behavior patterns of students in the online synchronous learning environment (Hou & Keng, 2021). In addition, adding gamification elements (Bai et al., 2020) to online asynchronous discussion activities to explore whether they can promote students' asynchronous interactive discussion is also a topic worthy of research (de la Peña et al., 2021).

Author Contribution Cheng-Tai Li: conceptualization, methodology, validation, formal analysis, investigation, data curation, writing original draft, and visualization.

Huei-Tse Hou: conceptualization, methodology, resources, writing, review, editing, supervision, project administration, and funding acquisition.

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Data Availability The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Declarations

Ethical Approval This article is original. We honestly and clearly presented the data and results in this study. Besides, we also cited appropriate and relevant literature in support of the claims made.

Informed Consent The participants' informed consent has been obtained.

Statement Regarding Research Involving Human Participants No ethical review was conducted for this study. However, we have obtained informed consent from the participants in this study.

Consent to Participate Before the experiment began, the researchers told participants about the purpose of the study and what their participation will involve. Participants can decide whether to take part in this research project and can withdraw at any time. If they choose to participate, they will be asked to fill out the informed consent document. Therefore, the participation of all students in this research was voluntary.

Consent for Publication The participants were aware of the data about their learning performance test and recording of discussion content and how it will be used and for what purpose. They consented to publish their data in a journal article.

Competing Interests The authors declare no competing interests.

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