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Designing cognitive-based game mechanisms for mobile educational games to promote cognitive thinking: an analysis of flow state and game-based learning behavioral patterns

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ABSTRACT

This study proposed a cognitive-based game mechanism based on the revised Bloom's taxonomy of cognitive processing dimensions. Moreover, a mobile Chinese history educational game, Void Broken: The Qing Dynasty, was developed based on the cognitive-based game mechanism to promote learners' cognitive thinking in history learning. This empirical study conducted an experiment with a quasi-experiment design and the participants were 70 high school freshmen from northern Taiwan, who were selected by convenience sampling. The present study analyzed the participants' historical knowledge gains and flow state. This study proposed an operational behavior coding scheme to analyze learning behaviors and evaluate the proposed cognitive-based game mechanism design and conducted sequential analyses to explore their learning behavioral patterns and their collaborative problem solving (CPS) behaviors in the game-based learning (GBL) process. The results suggested that the mechanism helped learners' historical knowledge gains, flow, and CPS behaviors. The high flow groups showed more multifaceted and active problem-solving behavioral patterns than the low flow groups. We suggest educational game designers consider including the cognitive-based game mechanism and flow antecedents into their game designs.

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KEYWORDS
Game-based learning; collaborative problem solving; behavioral pattern; flow; cognitive design; game mechanisms

1. Introduction

1.1 Game-based learning and serious games

Many studies have suggested that game-based learning (GBL) had positive influences on instruction (Amory & Seagram, 2003; Annetta, 2010; Annetta, Minogu, Holmes, & Cheng, 2009; Hou, 2012, 2013, 2015; Kiili, 2005, 2007; Kim, Park, & Baek, 2009) and facilitated history teaching (Spring, 2015). A history educational serious game might be integrated with learning objectives (e.g. people, periods, events, and locations) and game elements (Prensky, 2003). Moreover, the design of game mechanisms should be based on the learning theories. However, most previous educational serious game studies did not specify the mechanisms or the approaches behind the instructional contents of the game (Silva, 2020). Few of these studies explored the effects of game elements on game mechanism designs (Johnson, Horton, Mulcahy, & Foth, 2017). Since educational game mechanisms are the interface for players to apply knowledge to think and manipulate and complete the game tasks, it may be necessary to consider the learners' cognitive process.

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1.2 History instruction

Traditional history instructions were influenced by the cognitive-developmental theory (e.g. Wineburg, 2001), suggesting that children before age seventeen had limited abstract thinking skills, so their historical understanding and thinking skills were less developed. However, recent studies proved that even adolescents can comprehend abstract knowledge, including substantive and structural concepts in history learning (Brunner, 1990; Downey & Levstik, 1988; Egan, 2012; Elkind, 1981; Lee, Ashby, & Dickinson, 1996; Levstik, 1986; Levstik & Barton, 2011).

Substantive historical concepts were also called declarative knowledge, referring to the concepts of historical subject matters, including people, periods, events, locations, items, phenomena, technical terms, etc. These subject matters served as the basic elements for history construction and the main contents in historical texts. Without the understanding of these concepts, it would be much difficult to precisely convey ideas (Ritter, 1986), such as Socialism or Renaissance. These technical terms can explain complicated concepts succinctly and clearly.

Historical structural concepts were also called construct knowledge, referring to the knowledge produced through logical thinking based on evidence, accounts, causes, etc. (Lee et al., 1996). Such inference making abilities through integration and logical thinking cannot be solely obtained from historical texts. Students needed to learn how to explore history and further construct their own historical framework.

The transition from substantive to structural historical concepts is a cognitive process, which emphasized learners' active knowledge construction (Lee et al., 1996). The construction of learners' cognitive process could be helped by learning environments such as GBL.

1.3 Theoretical foundations of cognitive-based game mechanisms

To promote learners' cognitive thinking process during GBL, a cognitive-based game design was adopted to enhance learners' cognitive thinking and strategies in gameplay, based on the cognitive process dimension of the revised Bloom's taxonomy of educational objectives (Krathwohl & Anderson, 2009).

The design of cognitive-based game mechanism was based on cognitive processing levels, which corresponded to different functions in the game mechanism to promote learners' cognitive thinking. This design approach provides the game rules/functions that corresponded to cognitive levels (e.g. analysis, application, evaluation, etc.) in order to provide corresponding feedback and guidance as scaffolding. Hou et al. (2020) adopted Bloom's taxonomy in the design of cognitive-based functions for blog mind tools, which had positive effects on learning. However, this cognitive-oriented design has not been applied in educational games, so this study adopted the revised Bloom's taxonomy in the design of educational games.

In the revised Bloom's taxonomy of educational objectives, the cognitive domain had six levels, including remembering, understanding, applying, analyzing, evaluating, and creating (Krathwohl & Anderson, 2009). Each level followed the next level in order, and the next level was more complicated than the previous one (Krathwohl, 2002). In the level of understanding, learners needed to categorize historical knowledge properly for comparison. The level of applying served as the medium for understanding and analyzing. Learners needed to find proper methods and follow certain procedures for the learning tasks. Learners were given training activities to help transit from declarative knowledge to procedural logical thinking. The level of analysis further required learners to explore and construct knowledge.

Students used to memorize declarative knowledge from substantive concepts in history learning without going through the important cognitive process such as understanding, applying, and analyzing to promote their historical thinking skills (e.g. making historical connections and chronological reasoning). Although teachers could apply guided discussions to help students share their viewpoints based on the historical data, the students may lack highly autonomous motivation to make historical connections and chronological reasoning in historical knowledge. These limitations may thus bring challenges in historical thinking teaching.

Therefore, some scholars have listed pedagogical objectives for historical thinking skill instructions (The College Board, 2015; United Kingdom Government, Department for Education, 2013) For example, the curriculum framework by the College Board in the United States showed four types of historical thinking skills for students to develop, including analyzing historical sources and evidence, making historical connections, chronological reasoning and creating and supporting a historical argument. The United Kingdom and the domestic curriculum framework also instruct high school students should develop historical thinking skills.

Moreover, collaborative problem solving (CPS) can be an extremely effective instructional approach in developing conceptual understanding and cognitive strategies. The effective learning environments of CPS helped encourage learners to exchange ideas and information, to express their opinions, and to try out a variety of approaches in tasks (Nelson, 1999). Therefore, the present study conducted small-group-based GBL for CPS, and the researcher encouraged learners to discuss with their group members to complete instructional tasks.

The present study developed a history learning game as the experimental instrument, Void Broken, with the background of the Qing dynasty in China, 1644–1911. The theoretical foundation of this study included the cognitive process dimension of revised Bloom's taxonomy, which was integrated into the game as the cognitive-based game mechanism, and the four types of historical thinking skills from the College Board in the United States, which was integrated into the learning activities of the proposed mechanism. The mechanism designed based on the cognitive process dimension of revised Bloom's taxonomy (e.g. Hou et al., 2020) could be integrated into the game rules as the cognitive-based game mechanism to facilitate learners' understanding, applying, and analyzing of learning materials such as historical figures, events, biography, chronology, and locations. Learners could also exercise their historical thinking skills. The biographies of historical figures and the chronology of events were inserted into the contents of the game, and players could analyze these historical sources. Players needed to conduct chronological reasoning and make inferences based on the clues and design game strategies. By understanding and applying the clues to win the game, the players could also connect historical knowledge. Moreover, the GBL tasks were designed for CPS activities for small groups of learners. When learners had different or conflicting opinions during discussions, they could make a strong argument to convince other people and complete the learning tasks.

To enhance students' historical thinking skills, the game also created an attractive scenario and battle tasks to increase learners' motivation and involvement. Learners' high motivation helped promote their gameplay involvement, gaming experiences, pedagogical achievements, and their higher cognitive levels of longer memory maintenance (Driscoll, 1994; Jetton & Alexander, 2001; Pintrich, 2003). Because of the desire for better performance in games, students are driven by high motivation and triggered by self-adjustment-based learning (Schunk & Zimmerman, 2003).

As for the evaluation of the game mechanisms, this study analyzed players' historical knowledge gains, flow, and behavioral patterns. Csikszentmihalyi (2000) suggested that flow was a state of involvement. Being involved in the flow, students can tentatively concentrate on the targets and reduce outside disturbances. Kiili (2006), specifically for educational games, divided flow into two dimensions: flow antecedents and flow experiences. Antecedents included five sub-dimensions, including challenge, goal, feedback, control, and playability. Experiences included four sub-dimensions, including concentration, time distortion, autotelic experience, and loss of self-consciousness. Internal motivation was related to flow closely (Moneta, 2012) and played a significant factor in knowledge gains of GBL (Bressler & Bodzin, 2013). Therefore, the present study adopted the flow scale (Kiili, 2006) as the instrument to investigate students' motivation.

Behavioral pattern analysis for GBL could help further investigate learners' learning process and their reflection behaviors (e.g. Hou, 2015). The present study automatically recorded all the players' gameplay behaviors. Moreover, a large number of logs were retrieved after the experiment for the sequential analysis, exploring the players' behavioral patterns in the GBL process (e.g. Hou, 2012, 2013; Hsieh, Lin, & Hou, 2015). This helped explore whether the learners had the behaviors of applying and analyzing historical knowledge through GBL. This also helped investigate any possible behavioral pattern differences due to learners' high and low flow levels.

In recent years, many studies used the behavioral analysis in game-based learning to explore players' behavioral patterns (Cheng, Wang, Cheng, & Chen, 2019; Hou 2012, 2015; Hsiao, Tsai, & Hsu, 2020; Hwang, Chen, Chen, Wu, & Lai, 2019; Moon & Ke, 2020a, 2020b; Wen et al., 2018). Most of these studies explored learners' overall behavioral patterns in games (e.g. Hou 2012; 2015). Some studies explored the differences in behavioral patterns between high achievers and low achievers (Cheng, Wang, Cheng, & Chen, 2019; Hsiao, Tsai, & Hsu, 2020; Wen et al., 2018) and among learners with different peer-interaction efficiency (Moon & Ke, 2020a).

However, these previous studies did not design their game mechanisms based on cognitive levels. In this study, each mechanism corresponded to its specific cognitive levels. Therefore, we could know whether learners' behaviors in certain mechanisms reflected the corresponding cognitive levels with the behavioral pattern analysis. This study also explored differences in learning behaviors between high and low flow learner groups. Our analysis method that integrated cognitive level, flow, and behavioral pattern was innovative. This method was seldom discussed in studies on game-based learning behavioral patterns, but this method may be adopted to evaluate cognitive-based game mechanism.

1.4 Research questions

The present study thus has the following research questions:

1. Do participants' historical knowledge gains improve after the use of mobile game-based learning that integrates a cognitive mechanism design?
2. What is the participants' flow in the gaming process?
3. What are the differences of learning behavioral patterns between high flow groups and low flow groups?
4. What are participants' overall behavioral patterns in their collaborative problem-solving process?

2. Method

2.1 Participants

Seventy senior high school freshmen from northern Taiwan were selected in two high schools in northern Taiwan by convenience sampling. The students included 31 males and 39 females, and their ages were from 15 to 16. They had never used the educational game in this study, and they had not learned the lesson in this game. They have provided appropriate informed consent explanations by researchers before the study and they were all volunteered to join the test. Students were free to decide whether or not to participate in the study; they could withdraw their consent and withdraw from the study at any time during the study without any reason.

In the experimental group, thirty-five students (12 males and 23 females) were divided into groups of three to five people before the experiment, and there were 11 groups in total. The experimental group used the cognitive-based game developed by this study for the autonomous CPS activity. The other 35 students (19 males and 16 females) were in the control group, using the traditional reading method for learning.

2.2 Research design and procedure

The experiment was a quasi-experimental design and the total amount of time for the experimental group was about 100 min. In the beginning, the students conducted a pretest for ten minutes and then the researcher demonstrated another 10-min gameplay. After the introduction, each group of the students played the educational game named Void Broken – The Qing Dynasty with one mobile phone for 60 min. Next, they performed a 10-min posttest and a 10-min flow questionnaire. The pretest, posttest, and the flow evaluation were completed by individual student. The device for each group was an 8-inch mobile device where the game system was preloaded, and the network was disabled. During the experiment, the researchers did not intervene the students' game playing but only helped with technical problems. The students were told that the goal of the game was to win as many battles as possible within the time limit. They were allowed to discuss with their own group members only during the gameplay. The control group students conducted the same pretest and posttest as the experimental group students. Before the pretest, all the students read the history learning material, which had the same contents as the game. The students were allowed to read the material within 60 min, which was also the same time period for game play by the experimental group.

2.3 Instruments

2.3.1 The mobile educational game: Void Broken – The Qing Dynasty

The study developed a mobile history educational game to promote learners' cognitive thinking, Void Broken: The Qing Dynasty. The story of the game was about a time–space traveler, who accidentally returned to the ancient Chinese Qing Dynasty. Learners played the traveler to match chess pieces on a battle board (Figure 3). The battle board could collect the power of chess pieces against the monsters that had disturbed the time–space order. By defeating the monsters, the players could win all the battles and repair the broken historical memories to go back to the reality.

The game included 20 historical events and 50 historical figures of the Qing Dynasty. Each chess piece represented a figure, and each battle represented an event. The players could choose and place the chess pieces on the battle board according to the relations between the event and the figure. Different relations would bring different effects such as low damage effects from the matching attack and high damage effects from the critical attack in battles. The relations were hidden but the players would get hints from the game mechanism and the clues. By knowing these clues, the players could defeat the monsters easily, and learn more about the Qing Dynasty history.

2.3.2 The cognitive-based game mechanism

The game mechanism was designed based on the three cognitive dimensions of the revised Bloom's taxonomy of educational objectives, including Understand, Apply, and Analyze. The four main game mechanisms were Matching Attack, Critical Attack, Biography Reading, and Military Deployment, working with their corresponding cognitive dimensions and the related historical thinking skills, as shown in Table 1. The relations between figures and events included *Contemporary*, *Participant,* and *Irreverence*. *Contemporary* meant that a figure's lifetime span was across the event period. *Participant* meant that the figure's lifetime span was not only across the event period but also had an important influence on the event directly. *Irreverence* meant that a figure did not exist during the event period.

When the game began, the players could see a map of the ancient China in the Qing Dynasty on the screen. There were 20 battles on the map based on the locations of events in history. Before starting a battle, the players needed to select more than one chess piece from the Military Deployment interface (Figure 1, the left side), from which 50 chess pieces were available for the player to choose. Twenty chess pieces could be carried by the player for each single battle, and the players could decide how to use these chess pieces based on their arrangement. For example, the players could "apply" their historical knowledge in choosing the appropriate chess pieces, and "analyze" the game feedback to make an organized plan for battles.

By pressing the chess piece in the military deployment, the players would enter the Biography Reading interface (Figure 2, the right side) to read the figure's biography. The players could understand the relations between the chess pieces and the battles based on the given historical

Table 1. The four main game mechanisms.

Game Mechanisms	Behavior Explanation	The Cognitive Level of Three Cognitive Phases: Understand, Apply, and Analyze
Matching Attack	To drag and drop chess pieces on the battle board, activated by the Participant or Contemporary relations.	To *apply* historical knowledge on matching. To make their historical connections and analyze the utilization of chess pieces.
Critical Attack	To use a Participant relation chess piece and the other chess pieces with Contemporary relation in a row to activate a more powerful attack.	To *apply* historical knowledge for the matching attack first and *analyze* the participant relation and connect historical knowledge.
Biography Reading	To read the clues from biographies and to analyze the relations between the chess pieces and battles	To *understand* historical knowledge and *analyze* historical sources and evidence.
Military Deployment	To select chess pieces for battles	To *apply* historical knowledge in choosing chess pieces and *analyze* the game feedback to make an organized plan.

Note: The *Italicized* words refer to the related cognitive thinking behaviors and the underlined words refer to the related historical thinking skills.

document. This helped the players "understand" historical knowledge (including the figure's lifetime and related events), and "analyze" historical sources and evidence.

The Matching Attack was the less powerful attack and could be activated by the Contemporary relation. When the player dragged and dropped a chess piece belonging to the participant or contemporary relation to the event on the battle board, the monster would get injured by this matching attack. For example, when the four chess pieces belonging to the participant or contemporary relation were matched with The Boxer Rebellion event, the matching attack could be activated four times (Figure 3, the left side). No matter whether the matching was correct or not, the chess pieces would be consumed after the players used them. The Matching Attack helped the players "apply" historical knowledge in the matching and their historical connections. Because the carried chess pieces and the power of matching attacks were limited, the players had to "analyze" how to use the chess pieces wisely for the attack of more damages when encountering the more challenging monsters.

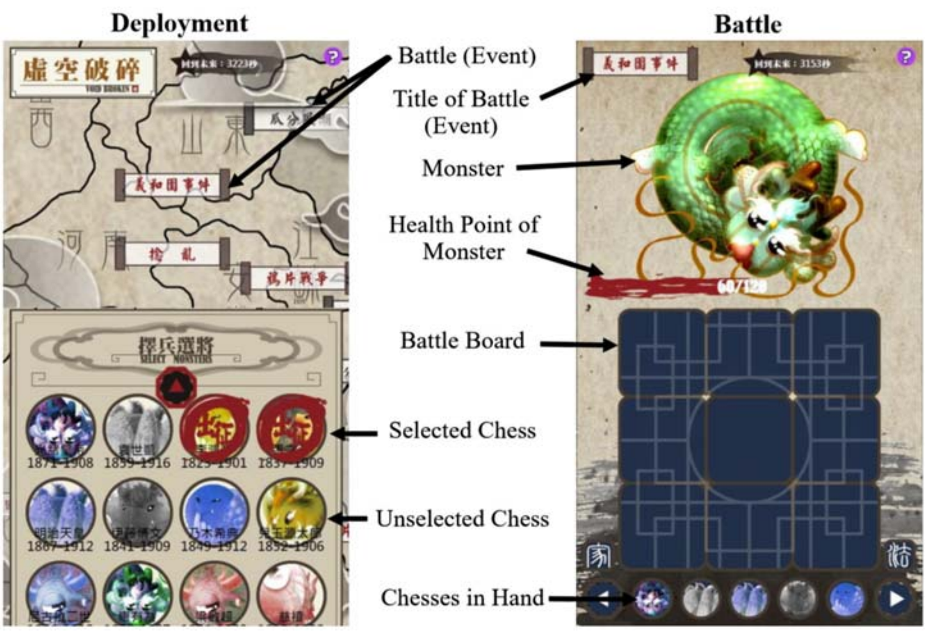

Figure 1. *Void Broken: The Qing Dynasty* (Left: To choose events and place chess piece).

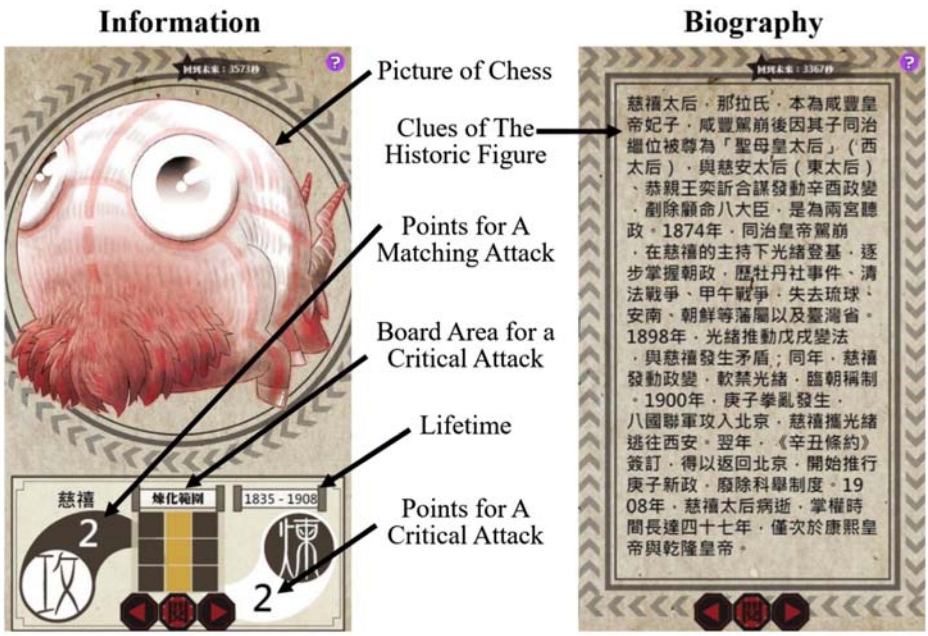

Figure 2. The chess piece (each chess piece represents one historical figure) and the biography of the historical figure.

Unlike the Matching Attack, the Critical Attack caused more damages but could only be activated by the Participant relation. When the player used a participant chess piece with the other three connected chess pieces in a row together (Figure 3, the right side) on the battle board, the critical attack could be activated. The attack power was multiplied by the game mechanism and caused more damages. The used chess pieces would disappear from the board after the successful or unsuccessful activation of critical attack. When planning a critical attack, the players needed to "apply" historical knowledge of the matching attack first, and "analyze" the participant relation between the chess pieces and the battles more thoroughly.

As the example in Figure 2 shows, the chess piece represents Empress Dowager Cixi, who was born in 1835 and died in 1908. The chess card also showed the power values of two attack types

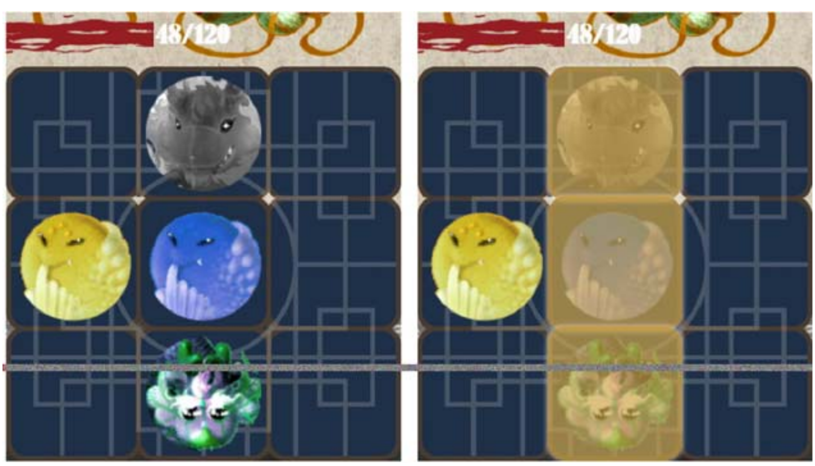

Figure 3. The battle scene (Left: Four chess pieces were placed on the battle board to activate the Matching Attack four times; Right: To use the three connected chess pieces in a row and sacrifice a chess to activate one Critical Attack).

(the Matching Attack and the Critical Attack) from the chess piece. In history, Empress Dowager Cixi was the most critical decision-maker in the politics of the Qing Dynasty. She also played an important role in many events in the latter part of the Qing Dynasty. Therefore, she had the participant relation for most events in the game, including the Boxer Rebellion event (Figure 1). There were four chess pieces on the battle board of the Boxer Rebellion (Figure 3, on the left side), showing that four participant or contemporary relation chess pieces were matched correctly. In the case shown by Figure 3, because Empress Dowager Cixi was the participant related to the Boxer Rebellion, the player could use the Empress Dowager Cixi chess piece and the other three connected chess pieces in a row to activate one critical attack. (Figure 3, the right side).

The players needed to strategically arrange their chess pieces to win the battles. They also needed to make their moves quickly because the monster would recover from injuries as time went by. In a highly challenging task, the players might have to defeat the monster by activating many critical attacks, suggesting that the players should analyze historical figures and events better in those difficult tasks.

2.3.3 The operational behavior coding scheme

The behavioral pattern analysis helped explore whether learners have behaviors of applying and analyzing in game-based learning. This also helped investigate possible learning behavioral patterns. To validate the game mechanisms and collect behavioral pattern data, the researchers inserted record labels as system logs into each function of the game system; therefore, the activation of the functions could be identified and coded for the behavioral pattern analysis. The game system automatically saved the operation logs in each device during the players' gameplay. The researchers created an operational behavior coding scheme and sorted out the logs into 11 items (Table 2) based on the game mechanisms and functions to explore learners' cognitive thinking behaviors and their related historical thinking behaviors.

For instance, the logs of entering military deployment interface were coded as "Start Organizing item" (O1), the behavior is considered that players might be applying their historical knowledge to analyze the chess pieces. The logs of entering biography interface and staying more than five

Table 2. Operational behavior coding scheme.

Code	Items	Descriptions/cognitive thinking behaviors and related historical thinking skills
O1	Start Organizing	To enter the military deployment interface, and *apply* the historical knowledge to *analyze* the chess pieces
O2	End Organizing	To leave the military deployment interface
R	Read Documents	To stay at the biography interface for more than 5 s, and *understand* and <u>*analyze* the historical sources and evidence</u>
A1	Matching Attack Successful	To activate one matching attack successfully by *applying* and *analyzing* the utilization of chess pieces To <u>infer the chorology</u> based on the contemporary relation and <u>connect historical knowledge</u>
A2	Matching Attack Unsuccessful	To activate one matching attack unsuccessfully due to the wrong judgment on the contemporary relation
A3	Critical Attack Successful	To activate one critical attack successfully by *applying* and *analyzing* the participant relation. To <u>infer the chorology</u> based on the participant relation and connect <u>historical knowledge</u>
A4	Critical Attack Unsuccessful	To activate one critical attack unsuccessfully due to the wrong judgment on the participant relation
FV	Victory Feedback	To win a battle
FD1	Defeat Feedback	To be defeated in a battle
FD2	Defeat Feedback Exhausted	To be defeated in a battle caused by running out of chess pieces
Q	Quitting Battles	To quit a battle actively

Note:
1. The *Italicized* words refer to the related cognitive thinking behaviors and the <u>underlined</u> words refer to the related historical thinking skills.
2. *Contemporary* is a relation that a figure's lifetime span was across the event period. *Participant* is a relation that a figure had an important influence on the event directly, and the participant must belong to the contemporary.

seconds were coded as the "Read documents item" (R), the behavior is considered that players might be understanding and analyzing historical sources and evidence. The logs of placing a chess piece on the battle board cause the monster receiving damage log were coded as the "Matching Attack Successful" item (A1), the behavior is considered that players might apply and analyze the utilization of chess pieces and inferring the chorology based on the contemporary relations. A chess piece, which belongs to the participant relation to the event, being sacrificed on the battle board were coded as the "Critical Attack successful" item (A3), the behavior is considered that players might apply and analyze the utilization of chess pieces to activate an effective attack. Both the two kinds of attacks made players connect their historical knowledge for winning the game. The log of conquering a battle was coded as the "Victory Feedback" item (FV). The pressing and confirming the quit button logs were coded as the "Quitting Battles" item (Q).

With the further sequential analysis of learners' encoded behaviors, we could better understand their problem-solving behavioral patterns. This study thus conducted a lag sequential analysis (Bakeman & Gottman, 1997; Hou, 2010) based on the coded codes. The lag sequential analysis could transfer potential group behavioral data into the visualized behavioral patterns. It could also help explore the sequential connection between behaviors that facilitated the learners' problem-solving processes in the game and the possible cognitive thinking process. For example, we could understand which gaming behavior came before and after another one and whether this behavioral sequence reached statistical significance. The procedure of a sequential analysis is as follows (Bakeman & Gottman, 1997; Hou, 2010). (1) Calculate the sequential transfer matrix (2) Calculate condition probability matrix (3) Calculate expect-value matrix (4) Calculate the adjusted residuals matrix and draw a sequential transfer diagram. There are already many studies using this analysis method to explore players' learning behaviors (Hou, 2012, 2013, 2015; Lin, Hou, Wu, & Chang, 2014; Wang, Hou, & Wu, 2017).

The adjusted residuals matrix (*Z* scores) was calculated to test the transitional probabilities that were significantly higher and lower than the expected probability (Bakeman & Quera, 1995). The value (*Z*-score) was used to validate whether the continuity of the sequence reached statistical significance. If the value of a behavioral sequence in the adjusted residuals matrix was above 1.96, it reached statistical significance ($p < .05$) and the behavior sequence would be depicted in the final sequential transfer diagram. The *Z*-scores would be marked in the diagram with the degree of significance of the sequences, but the scores could not be used directly for the cross-group comparison. These diagrams helped explore whether the learners showed certain behaviors. The coded data was ordered chronologically for the later sequential analysis.

2.3.4 The evaluation of historical knowledge gains

The historical knowledge gains evaluation was developed by the researcher, and the items were reviewed by an expert to ensure the expert validity. The expert was a history teacher, who had a nine-year history instruction experience. The evaluation included a pretest and a posttest. The contents of these two tests were identical, but the order of the test items was different to avoid students' memory effect. These questions were related to the historical contents shown in the game, including 20 multiple choice questions about the Qing Dynasty. Each question had five points and the total points were 100.

2.3.5 The flow scale evaluation

The study used the Flow Scale for Games (FSG) by Killi (2006) to evaluate learners' involvement in the game. Flow referred to a person's higher cognitive involvement when participating in a certain activity. The FSG scale included nine dimensions, which are Challenge, Goal, Feedback, Control, Playability, Concentration, Time distortion, Autotelic experience, and Loss of self-consciousness. Each dimension measured learners' different feelings of involvement in activities. For example, the dimension Challenge measured whether learners could feel the balance between challenges in the game and their own skills. The two items of the Challenge dimension were below: "*I was challenged, but I* *believed my skills would allow me to meet the challenge.*", "*The challenge that the game provided and my skills were at an equally high level.*"

The scale was a Likert five-point scale, including 23 questions. The study used the Chinese version of the scale, translated by Hou and Chou (2012). According to the analysis of data in the experimental group ($n = 35$), the internal consistency was high (Cronbach's $\alpha = .905$) and the reliability of the scale was excellent. This scale was also widely used in many GBL studies (Hou, 2015; Hou & Li, 2014).

3. Results

3.1 Historical knowledge gains

An independent-sample *t*-test was conducted to compare the homogeneity of pretest between the experimental group and the control group before the analysis of covariance. There was no significant difference ($t = 1.814$, $p = .074 > .05$) in the pretest between the experimental group and the control group. A paired-sample *t*-test was conducted to compare the students' pretest and posttest scores in the experimental group and control group (Table 3). There was a significant difference ($t(34) = 2.623$, $p = .013 < .05$) in the experimental group's scores between the pretest and the posttest. There was no significant difference ($t(34) = 0.934$, $p = .357 > .05$) in the control group's scores between the pretest and the posttest. These results suggested that the students' historical knowledge gains were enhanced only in the experimental group not in the control group.

As for the comparison between experimental group and control group, before reporting a one-way analysis of covariance (one-way ANCOVA), this study conducted a test of homogeneity of regression coefficients within groups, the result indicated there is no significant interaction effect, $F(1,66) = 2.992$, $p > .05$. The result suggests that it can continue the one-way analysis of covariance.

A one-way ANCOVA was conducted to determine if there was any significant difference between groups on posttest controlling for pretest (Table 4). There was no significant differential effect of group on posttest, $F(1, 67) = 2.702$, $p = .105 > .05$. The result suggested that there was no significant difference in the posttest scores between the experimental group and the control group.

3.2 Flow scale

A one-samples *t*-test was conducted to compare the score of the participant's flow scale evaluation and the median score of the scale in the educational game experiment (Table 5). There was a significant difference ($t(34) = 11.767$, $p = .000 < .001$) in the scores for an average of all dimensions ($M = 4.102$, SD = 0.554) and the medium value (the medium is 3.000 in a five-point scale). The flow scale included nine dimensions, which indicated the degree of involvement experienced by the students in the game. The results showed that the means of all dimensions were significantly above the medium. This finding suggested that the students were deeply involved in the game and the game enhanced the students' flow involvement. As Table 5 shows, the mean of all the nine dimensions was 4.102, and the design of the game elements (Prensky, 2003) might also help the students get involved in GBL.

3.3 Differences in behavioral patterns between high flow and low flow groups

The study recorded all the participants' operational behaviors (11 groups in total) and had 4460 codes for the sequential analysis. Any sequences that reached a significant level in the adjusted

Table 3. A paired *t*-test for historical knowledge gains.

	Pretest		Posttest		
Historical Knowledge Gains	*M*	SD	*M*	SD	*t*
Experimental	61.286	11.203	66.429	11.917	2.623*
Control	56.000	13.106	57.857	16.816	0.934

*$p < .05$.

Table 4. ANCOVA results and descriptive statistics for posttest by group.

Variable	Group	*N*	Mean	SD	Adjusted Mean	Adjusted SD	*F*
Posttest	Experimental	35	66.429	11.917	64.432	1.946	2.702
	Control	35	57.857	16.816	59.854	1.946	

Table 5. One sample *t*-test for flow of means (test value = 3).

	Test value = 3.000		
Dimensions	*M*	SD	*t*
Challenge	4.229	0.761	9.556***
Goal	4.129	0.808	8.268***
Feedback	3.929	0.778	7.062***
Control	3.929	0.806	6.818***
Playability	3.700	1.001	4.135***
Concentration	4.243	0.768	9.572***
Time distortion	4.214	0.789	9.110***
Autotelic experience	4.386	0.718	11.413***
Loss of self-consciousness	3.543	1.227	2.617*
Average of all dimensions	4.102	0.554	11.767***

*$p < .05$, ***$p < .001$.

residuals matrix (Table 6) were depicted in the sequential transfer diagram to explore the students' gaming behavioral patterns. In this table, if the value (*Z* score) of a behavioral sequence in the adjusted residuals matrix was above 1.96, the behavior sequence reached the significant level ($p < .05$) and it was depicted in the final sequential transfer diagram (Figure 6).

To evaluate the mean of flow in each group, the present study calculated all the students' sum of flow scores and divided the sum by the number of the students in each group. Based on the means of the eleven groups, we could determine the degree of involvement by the students in each group. The study chose the top 27% as the high flow groups (three groups) and the bottom 27% as the low flow groups (three groups). The flow scores of the six groups were shown in Table 7. The sequential analysis of high flow groups and low flow groups were both conducted by using the *Z*-score calculation process mentioned above to explore their behavioral patterns in the high and low flow groups, as shown in Figures 4 and 5. The arrows in the figures showed the direction of significant sequences, and the numbers in the figures represented the *Z*-scores, indicating the significance degree of the sequences within each group.

According to the figures, unlike the low flow groups, the high flow groups tended to reorganize their military deployment (A2→FD2, A2→FD1, FD1→O1) right after their attacks had failed (A2, A4). The high flow groups also tended to leave the battle early to reorganize their deployment after they analyzed the battle situations (A4→Q, Q→O1). The high flow groups usually went back to the

Table 6. Adjusted residuals matrix (*Z* score) of all students.

Z	O1	O2	R	A1	A2	A3	A4	FV	FD1	FD2	Q
O1	−11.74	62.84*	3.80*	−23.71	−6.02	−9.31	−7.76	−3.58	−0.42	−4.56	−1.40
O2	43.72*	−11.79	−4.68	−8.59	−1.68	−9.27	−7.73	−3.56	−0.42	−4.54	−1.39
R	−4.66	3.80*	48.00*	−9.41	−2.39	−3.69	−3.08	−1.42	−0.17	−1.81	−0.56
A1	−23.50	−23.71	−9.41	31.52*	−4.02	14.48*	1.08	−4.01	−0.84	−2.19	−1.58
A2	−5.97	−6.02	−2.39	−0.45	31.64*	−3.75	−3.37	−1.82	4.67*	2.32*	3.71*
A3	−9.23	−9.31	−3.69	4.09*	−0.07	1.43	6.82*	20.43*	−0.33	2.77*	0.92
A4	−7.69	−7.76	−3.08	−4.50	−2.80	5.45*	19.30*	−2.34	−0.28	14.77*	3.79*
FV	20.04*	−3.53	−1.40	−7.06	−1.79	−2.77	−2.31	−1.07	−0.13	−1.36	−0.42
FD1	2.39*	−0.42	−0.17	−0.84	−0.21	−0.33	−0.28	−0.13	−0.01	−0.16	−0.05
FD2	25.54*	−4.50	−1.78	−9.00	−2.28	−3.53	−2.95	−1.36	−0.16	−1.73	−0.53
Q	7.95*	−1.40	−0.56	−2.80	−0.71	−1.10	−0.92	−0.42	−0.05	−0.54	−0.17

*$p < .05$.

Table 7. Descriptive statistics for high flow groups and low flow groups.

	High Flow G1		High Flow G2		High Flow G3		Low Flow G1		Low Flow G2		Low Flow G3	
Dimensions	*M*	SD	*M*	SD	*M*	SD	*M*	SD	*M*	SD	*M*	SD
Challenge	5.000	0.000	4.667	0.577	3.750	0.354	3.875	0.854	3.500	1.414	3.500	0.707
Goal	5.000	0.000	4.833	0.289	4.000	0.000	3.875	1.031	3.000	1.414	3.000	0.000
Feedback	4.750	0.354	5.000	0.000	3.750	0.354	3.875	0.750	3.750	0.354	2.500	0.707
Control	4.500	0.707	5.000	0.000	4.500	0.000	4.000	0.707	3.000	0.000	3.250	0.354
Playability	5.000	0.000	4.000	1.732	3.000	0.000	3.375	1.250	2.750	1.768	3.250	0.354
Concentration	4.250	1.061	5.000	0.000	4.750	0.000	3.688	1.008	3.375	0.177	3.000	0.354
Time distortion	5.000	0.000	4.167	1.443	4.500	0.707	4.125	0.854	4.500	0.707	3.500	0.707
Autotelic experience	4.750	0.354	5.000	0.000	4.625	0.530	3.688	0.718	4.250	0.707	3.250	0.000
Loss of self-consciousness	4.500	0.000	3.667	2.309	4.500	0.707	3.875	1.109	4.500	0.000	3.750	1.768
Average of all dimensions	4.717	0.277	4.681	0.552	4.261	0.307	3.793	0.396	3.696	0.369	3.192	0.406

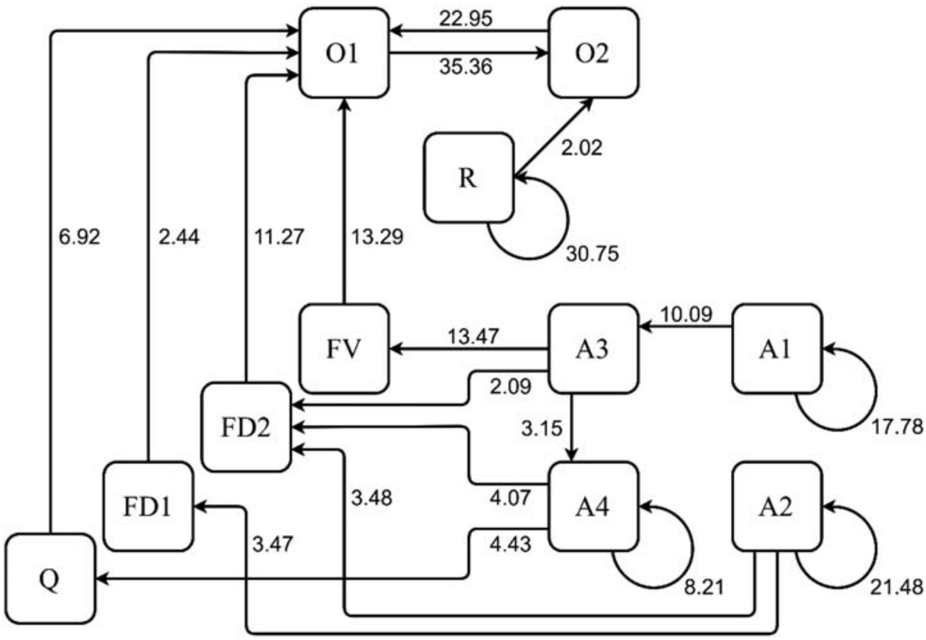

Figure 4. The behavioral pattern analysis of high flow groups.

interface immediately to reanalyze historical knowledge and reorganize chess pieces (FD1→O1) right after they failed the mission from trials and errors. This sequence was not found in the low flow groups. These findings may suggest that the students actively analyzed the relations between the figures and the events. Unlike the low flow groups, the high flow groups showed behaviors of understanding and analyzing historical knowledge by reading information many times (R→R). It is possible that the game in this study enhanced the students' flow involvement, thus increasing their involvement behaviors in searching the correct chess pieces for battles, e.g. repetitive behaviors in analyzing information (R→R) and confirming information (A2→FD2, A2→FD1, A4→Q).

Unlike the high flow groups, the low flow groups tended to repeat their successful and unsuccessful attacking behaviors many times (A1→A2, A2→A1, A4→A4, A3→A3). They did not reorganize their chess deployment after failure (e.g. A1→A2, A2→A1, A4→A4, A3→A3) or leave the battle early for the reorganization (A4→Q) as the high flow groups did. Compared to the high flow groups, the low flow groups showed more conservative problem-solving strategies and less trial and error behaviors. Moreover, the low flow groups did not show the sequence of repeated reading for historical knowledge analysis (R→R). They also seldom actively analyzed information or adjusted their strategies.

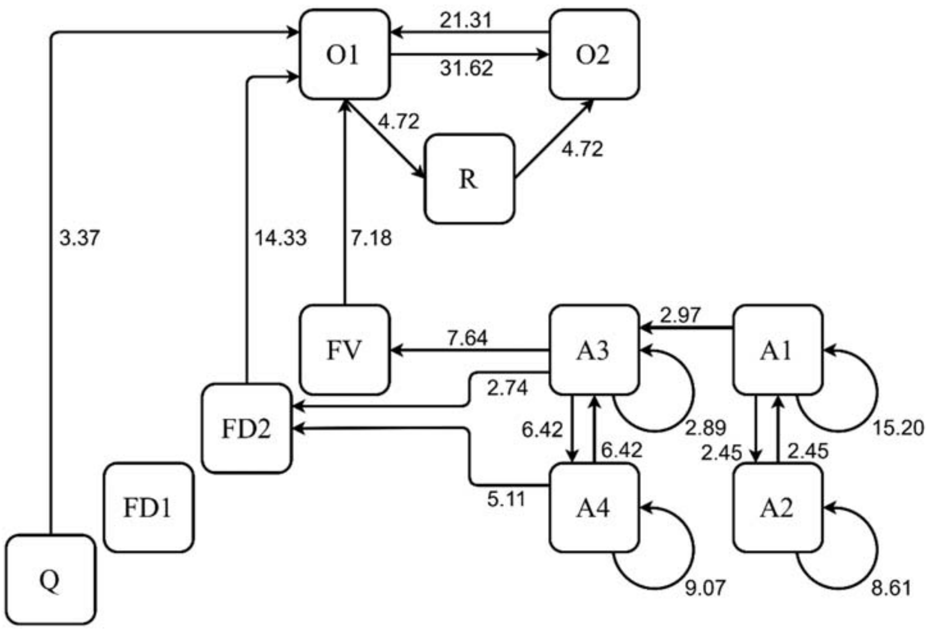

Figure 5. The behavioral pattern analysis of low flow groups.

These results showed that both high and low flow groups had their own ways to solve problems. The high flow group had more active information analysis behaviors and strategy adjustment behaviors, while the low flow groups tended to be more conservative. The goal of the game was for players to complete as many missions as possible within a limited time. If the mission was not completed, the players could start it all over again. Therefore, the main strategy used by the high flow groups in the game was to actively analyze historical knowledge (R→R) with constant trial and error behaviors (A2→FD2, A2→FD1, FD1→O1, A4→Q, Q→O1). A study analyzing problem-solving behaviors in educational games by Hou (2015) also found that students in high flow groups showed more reflective behaviors.

3.4 Overall behavioral patterns

Regarding the overall behavioral patterns of all the students, as shown in Figure 6, we summarized these important sequences related to the students' active problem-solving behavioral patterns as follows.

(1) We found that the three sequences of O1→O2, O2→O1, and R→R were all statistically significant. This finding showed that the students repeated reading to understand the information about historical figures, and they analyzed and planned for the chess deployment in the game. The sequence of repeated reading and analysis (R→R) was significant, suggesting that the students were deeply involved in the reading behavior when they were playing the game.
(2) Moreover, the sequences related to the students' learning behaviors were also the sequences related to their attacking behaviors. We found that the sequences of A1→A1, A1→A3, and A3→A1 were significant, suggesting that the students had chances to activate successful matching attacks and critical attacks in the game. The students could activate a successful matching attack and a follow-up critical attack by "analyzing" and "applying" historical knowledge. This behavioral pattern suggested that the students could analyze and design successful attacking strategies rather than depend on random trials and errors. This behavioral pattern was similar to the arguments by Killi (2007) that learners created new strategies to solve problems in

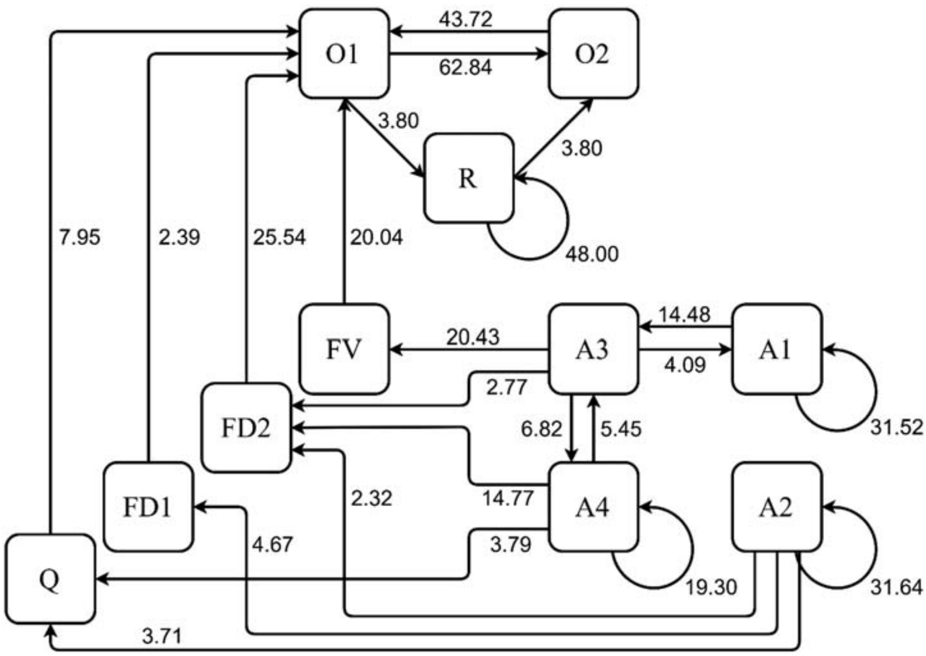

Figure 6. Students' problem-solving behavioral patterns (all students).

their reflection process in problem-based gaming. This pattern was also found in some other GBL research and it could help learners' reflections and their problem-solving abilities (Hou, 2015). This finding also suggested that a game mechanism that was designed to promote learners' cognitive thinking levels may enhance their problem-solving abilities.

Based on these two behavioral patterns above, we could find that the students might analyze and understand historical knowledge during reading. They also "applied" and "analyzed" historical knowledge to choose and organize chess pieces for the best deployment in the battle. In addition, the students could activate successful attacks by "analyzing" and "applying" historical knowledge in the battle. Unlike memory-based learning, this behavioral pattern may assist learners to develop important competencies, such as analyzing, inference making, and planning. Reflections and planning were important elements in metacognition. The game mechanism in this study was designed based on cognitive theories, and it may help learners use knowledge and develop the three types of historical thinking competencies (The College Board, 2015; United Kingdom Government, Department for Education, 2013), including Analyzing Historical Sources and Evidence, Making Historical Connections, and Chronological Reasoning.

This present study further analyzed the relations between students' flow states and their learning processes in a CPS context (Nelson, 1999; Roschelle & Teasley, 1995). Compared to other previous studies (e.g. Hou, 2015) that analyzed the flow of one single player in the game process, this study further explored the differences of learning behavioral patterns between the students with different flow levels in a CPS task. The study found that high flow groups had more multifaceted and active problem-solving, reflective, and analyzing behaviors.

4. Discussions and conclusions

The study designed a game mechanism based on the revised Bloom's cognitive theories (Krathwohl & Anderson, 2009) to help students develop the three historical thinking competencies (The College

Board, 2015; United Kingdom Government, Department for Education, 2013), including analyzing historical sources and evidence, making historical connections, chronological reasoning and creating and supporting a historical argument. The first three competencies might be developed during the gameplay according to the definition of the operational coding scheme and the results of the behavioral pattern analysis. The fourth competence "creating and supporting a historical argument" might also be used by the students during the CPS discussions when the learners had different or conflicting opinions in groups. However, the effectiveness of this competence may need more future research to support (e.g, video analysis and content analysis of discussion contents) (e.g. Hou, 2015; Hou et al., 2020).

With the cognitive-based game mechanism in this study, the game could enhance the students' development in understanding, applying, and analyzing historical knowledge. The study also explored the students' historical knowledge gains, flow, and learning behavioral patterns in the CPS activity by using the game. Although there was no significant difference in the posttest scores between the experimental group and the control group, this study found that historical knowledge of the experimental group improved. The control group, however, did not show this improvement. The results of the study showed that students' historical knowledge gains were significantly enhanced after they used the game, and they also had high flow involvement. The results indicated that the integration of cognitive-based mechanism (e.g. Hou et al., 2020) and game elements (Prensky, 2003) could form a cognitive-based game mechanism to promote learners' cognitive thinking.

The further learning behavioral pattern analysis also displayed that the students repeated reading historical knowledge in the game, and they applied and analyzed historical knowledge to organize their chess pieces for strategy planning. This helped learners' reflections and may promote their problem-solving abilities that were found in some other GBL research (e.g. Hou, 2015; Kiili, 2007).

Moreover, the students activated successful attacks by analyzing and applying historical knowledge in the battle. The game mechanism not only helped the students memorize knowledge but also facilitated their historical thinking competence by encouraging them to analyze, plan, and make inferences. This finding also suggested that a cognitive-based game mechanism design might promote learners' cognitive thinking levels and help enhance their problem-solving abilities.

Since it could be difficult for one single student to analyze historical knowledge alone, students in this study were assigned into groups for problem-solving discussions in a CPS gaming activity, where the students could gain support and scaffolding from each other. The study calculated the mean of flow scores from all the students in the same group, and the mean from each group was seen as the degree of its involvement. The study analyzed the differences of learning behavioral patterns between the high flow groups and the low flow groups. The results indicated that the high flow groups showed more multifaceted and active problem-solving, reflective, and analyzing behaviors. Moreover, the high flow groups showed more trial and error behaviors and were more involved in biography reading and information analysis.

Based on these findings, the research has the following suggestions for educational game designers and future studies:

(1) As for the educational game design, we found that a game mechanism designed based on cognitive theories helped enhance learners' cognitive thinking. This study designed the corresponding functions and game mechanism based on learners' cognitive thinking levels (e.g. analysis, application, evaluation, etc.), helping designers create educational games that promoted cognitive thinking. The mechanism proposed by this study may also be modified and adopted in educational games for other subject teaching.
(2) As for the learning process and flow, since educational games require more cognitive involvement than ordinary games, students' flow involvement and internal motivation are especially needed (Perttula, Kiili, Lindstedt, & Tuomi, 2017). In this study, we found that flow had positive impacts on learners' reflective and planning behaviors in CPS and GBL activity. Therefore,

designing a game that can enhance learners' flow is the key to the future educational game design. Other previous studies also suggested that the antecedents for flow enhancement in educational games (Csikszentmihalyi, 2000; Kiili, 2006) (e.g. a sense of control, clear goals, unambiguous feedback, challenges matched to the skill level of a player, playability, etc.) could influence learners' flow experiences. Therefore, we suggest that educational game designers take flow antecedents into account when designing games.

(3) As for the educational research, this study adopted behavioral pattern analysis to explore whether the expected corresponding learning behaviors would appear in the design of certain game functions for promoting learners' cognitive thinking. We also explored learning process on the basis of learning effectiveness, flow, and behavioral patterns. This may help educational game developers to evaluate game-based learning

(4) The study focused on the design of cognitive mechanism in games, flow, learning effectiveness, and behavioral pattern analysis. After confirming the positive effects of our mechanism, we will adjust and improve our game based on the results of this study. In the future, it is suggested to explore game-based learning effectiveness and behavioral patterns of learners from more different regions or in different educational policy settings. In the aspect of analysis approaches, analyzing learners' discussion contents in the game is another good way to understand the role of cognitive levels (e.g. Hou et al., 2020) and learners' social knowledge construction process in their discussion. This can help the researchers more deeply analyze and evaluate the effectiveness of "learning by playing" and serve as references for future educational game designs.

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Disclosure statement

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References

Amory, A., & Seagram, R. (2003). Educational game models: Conceptualization and evaluation: The practice of higher education. *South African Journal of Higher Education*, *17*(2), 206–217. https://doi.org/10.10520/EJC36981

Annetta, L. A. (2010). The "I's" have it: A framework for serious educational game design. *Review of General Psychology*, *14*(2), 105–113. https://doi.org/10.1037/a0018985

Annetta, L. A., Minogue, J., Holmes, S. Y., & Cheng, M. T. (2009). Investigating the impact of video games on high school students' engagement and learning about genetics. *Computers & Education*, *53*(1), 74–85. https://doi.org/10.1016/j.compedu.2008.12.020

Bakeman, R., & Gottman, J. M. (1997). *Observing interaction: An introduction to sequential analysis*. Cambridge University Press.

Bakeman, R., & Quera, V. (1995). *Analyzing interaction: Sequential analysis with SDIS and GSEQ*. Cambridge University Press.

Bressler, D. M., & Bodzin, A. M. (2013). A mixed methods assessment of students' flow experiences during a mobile augmented reality science game. *Journal of Computer Assisted Learning*, *29*(6), 505–517. https://doi.org/10.1111/jcal.12008

Bruner, J. S. (1990). *Acts of meaning* (Vol. 3). Harvard University Press.

Cheng, Y. W., Wang, Y., Cheng, I. L., & Chen, N. S. (2019). An in-depth analysis of the interaction transitions in a collaborative augmented reality-based mathematic game. *Interactive Learning Environments*, *27*(5–6), 782–796. https://doi.org/10.1080/10494820.2019.1610448

The College Board. (2015). AP historical thinking skills. https://www.collegeboard.org/

Csikszentmihalyi, M. (2000). *Beyond boredom and anxiety*. Jossey-Bass.

Downey, M. T., & Levstik, L. S. (1988). Teaching and learning history: The research base. *Social Education*, *52*(5), 336–342.

Driscoll, M. P. (1994). *Psychology of learning for instruction*. Allyn & Bacon.

Egan, K. (2012). *Primary understanding: Education in early childhood* (Vol. 27). Routledge.

Elkind, D. (1981). Child development and the social science curriculum of the elementary school. *Social Education*, *45*(6), 435–437.

Hou, H. T. (2010). Exploring the behavioural patterns in project-based learning with online discussion: Quantitative content analysis and progressive sequential analysis. *Turkish Online Journal of Educational Technology-TOJET*, *9*(3), 52–60.

Hou, H. T. (2012). Exploring the behavioral patterns of learners in an educational massively multiple online role-playing game (MMORPG). *Computers & Education*, *58*(4), 1225–1233. https://doi.org/10.1016/j.compedu.2011.11.015

Hou, H. T. (2013). Analyzing the behavioral differences between students of different genders, prior knowledge and learning performance with an educational MMORPG: A longitudinal case study in an elementary school. *British Journal of Educational Technology*, *44*(3), E85–E89. https://doi.org/10.1111/j.1467-8535.2012.01367.x

Hou, H. T. (2015). Integrating cluster and sequential analysis to explore learners' flow and behavioral patterns in a simulation game with situated-learning context for science courses: A video-based process exploration. *Computers in Human Behavior*, *48*, 424–435. https://doi.org/10.1016/j.chb.2015.02.010

Hou, H. T., & Chou, Y. S. (2012). Exploring the technology acceptance and flow state of a chamber escape game-escape the lab for learning electromagnet concept. In Proceedings of the 20th International Conference on Computers in Education (Vol. 38).

Hou, H. T., & Li, M. C. (2014). Evaluating multiple aspects of a digital educational problem-solving-based adventure game. *Computers in Human Behavior*, *30*, 29–38. https://doi.org/10.1016/j.chb.2013.07.052

Hou, H. T., Yu, T. F., Chiang, F. D., Lin, Y. H., Chang, K. E., & Kuo, C. C. (2020). Development and evaluation of mindtool-based blogs to promote learners' higher order cognitive thinking in online discussions: An analysis of learning effects and cognitive process. *Journal of Educational Computing Research*, *58*(2), 343–363. https://doi.org/10.1177/0735633119830735

Hsiao, H. S., Tsai, F. H., & Hsu, I. Y. (2020). Development and evaluation of a computer detective game for microbial food safety education. *Journal of Educational Computing Research*, *58*(6), 1144–1160. https://doi.org/10.1177/0735633120924924

Hsieh, Y. H., Lin, Y. C., & Hou, H. T. (2015). Exploring elementary-school students' engagement patterns in a game-based learning environment. *Journal of Educational Technology & Society, 18*(2), 336–348.

Hwang, G. H., Chen, B., Chen, R. S., Wu, T. T., & Lai, Y. L. (2019). Differences between students' learning behaviors and performances of adopting a competitive game-based item bank practice approach for learning procedural and declarative knowledge. *Interactive Learning Environments*, *27*(5–6), 740–753. https://doi.org/10.1080/10494820.2019.1610458

Jetton, T. L., & Alexander, P. A. (2001). Interest assessment and the content area literacy environment: Challenges for research and practice. *Educational Psychology Review*, *13*(3), 303–318. https://doi.org/10.1023/A:1016680023840

Johnson, D., Horton, E., Mulcahy, R., & Foth, M. (2017). Gamification and serious games within the domain of domestic energy consumption: A systematic review. *Renewable and Sustainable Energy Reviews*, *73*, 249–264. https://doi.org/10.1016/j.rser.2017.01.134

Kiili, K. (2005). Digital game-based learning: Towards an experiential gaming model. *The Internet and Higher Education*, *8* (1), 13–24. https://doi.org/10.1016/j.iheduc.2004.12.001

Kiili, K. (2006). Evaluations of an experiential gaming model. *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments*, *2*(2), 187–201. https://doi.org/10.17011/ht/urn.2006518

Kiili, K. (2007). Foundation for problem-based gaming. *British Journal of Educational Technology*, *38*(3), 394–404. https://doi.org/10.1111/j.1467-8535.2007.00704.x

Kim, B., Park, H., & Baek, Y. (2009). Not just fun, but serious strategies: Using meta-cognitive strategies in game-based learning. *Computers & Education*, *52*(4), 800–810. https://doi.org/10.1016/j.compedu.2008.12.004

Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: An overview. *Theory Into Practice*, *41*(4), 212–218. https://doi.org/10.1207/s15430421tip4104_2

Krathwohl, D. R., & Anderson, L. W. (2009). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. Longman.

Lee, P., Ashby, R., & Dickinson, A. (1996). Progression in children's ideas about history. *Bera Dialogues*, *11*, 50–81.

Levstik, L. S. (1986). Teaching history: A definitional and developmental dilemma. In V. A. Atwood (Ed.), *Elementary school social studies: Research as a guide to practice* (pp. 68–84). National Council for the Social Studies.

Levstik, L. S., & Barton, K. C. (2011). *Doing history: Investigating with children in elementary and middle schools*. Routledge.

Lin, P. C., Hou, H. T., Wu, S. Y., & Chang, K. E. (2014). Exploring college students' cognitive processing patterns during a collaborative problem-solving teaching activity integrating Facebook discussion and simulation tools. *The Internet and Higher Education*, *22*, 51–56. https://doi.org/10.1016/j.iheduc.2014.05.001

Moneta, G. B. (2012). Opportunity for creativity in the job as a moderator of the relation between trait intrinsic motivation and flow in work. *Motivation and Emotion*, *36*(4), 491–503. https://doi.org/10.1007/s11031-012-9278-5

Moon, J., & Ke, F. (2020a). Exploring the relationships among middle school students' peer interactions, task efficiency, and learning engagement in game-based learning. *Simulation & Gaming, 51*(3), 310-335. https://doi.org/10.1177/1046878120907940

Moon, J., & Ke, F. (2020b). In-game actions to promote game-based math learning engagement. *Journal of Educational Computing Research*, *58*(4), 863–885. https://doi.org/10.1177/0735633119878611

Nelson, L. M. (1999). Collaborative problem solving. In C. M. Reigeluth (Ed.), *Instructional design theories and models: A new paradigm of instructional theory* (Vol. 2, pp. 241–267). Lawrence Erlbaum Associates.

Perttula, A., Kiili, K., Lindstedt, A., & Tuomi, P. (2017). Flow experience in game based learning – A systematic literature review. *International Journal of Serious Games*, *4*(1), 57–72. https://doi.org/10.17083/ijsg.v4i1.151

Pintrich, P. R. (2003). A motivational science perspective on the role of student motivation in learning and teaching contexts. *Journal of Educational Psychology*, *95*(4), 667–686. https://doi.org/10.1037/0022-0663.95.4.667

Prensky, M. (2003). Digital game-based learning. *Computers in Entertainment*, *1*(1), 21–21. https://doi.org/10.1145/950566.950596

Ritter, H. (1986). *Dictionary of concepts in history (No. 3)*. Greenwood Publishing Group.

Roschelle, J., & Teasley, S. D. (1995). The construction of shared knowledge in collaborative problem solving. In C. E. O'Malley (Ed.), *Computer supported collaborative learning* (pp. 69–97). Springer.

Schunk, D. H., & Zimmerman, B. J. (2003). Self-regulation and learning: Handbook of psychology. *Educational Psychology*, *7*, 59–78. https://doi.org/10.1002/9781118133880.hop207003

Silva, F. G. M. (2020). Practical methodology for the design of educational serious games. *Information*, *11*(1), 14. https://doi.org/10.3390/info11010014

Spring, D. (2015). Gaming history: Computer and video games as historical scholarship. *Rethinking History*, *19*(2), 207–221. https://doi.org/10.1080/13642529.2014.973714

United Kingdom Government, Department for Education. (2013). National curriculum in England: history programmes of study. https://www.gov.uk/

Wang, S. M., Hou, H. T., & Wu, S. Y. (2017). Analyzing the knowledge construction and cognitive patterns of blog-based instructional activities using four frequent interactive strategies (problem solving, peer assessment, role playing and peer tutoring): a preliminary study. *Educational Technology Research and Development*, *65*(2), 301–323. https://doi.org/10.1007/s11423-016-9471-4

Wen, C. T., Chang, C. J., Chang, M. H., Chiang, S. H. F., Liu, C. C., Hwang, F. K., & Tsai, C. C. (2018). The learning analytics of model-based learning facilitated by a problem-solving simulation game. *Instructional Science*, *46*(6), 847–867. https://doi.org/10.1007/s11251-018-9461-5

Wineburg, S. (2001). *Historical thinking and other unnatural acts: Charting the future of teaching the past*. Temple University Press.