3D Periodic-Sugoroku Game for Active Learning of the Periodic Table

Chapter X

3D Periodic Sugoroku Game for Active Learning of the Periodic Table

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Abstract. The periodic table is an important set of scientific symbols that are not commonly used in everyday life but which may cause science phobia in youngsters. Many types of educational tools for learning the periodic table do not provide an opportunity to discover the relationships between chemical elements. In this study, we propose a NEO GAME of *sugoroku* game involving a 3D periodic chart (i.e., *periodic-sugoroku*) for use as an educational tool. *Sugoroku* is a Japanese board game similar to *Parcheesi* or *Monopoly*. Using this proposed tool, students can actively learn the periodic chart while enjoying a *sugoroku* game.

Keywords. Select the significant words of the paper. The keywords should be separated by commas.

1. Introduction

A segment of the young population in Japan exhibits a lack of interest in scientific knowledge or methodology. This phenomenon of science phobia is an important problem. Some scientific symbols induce this science phobia. However, scientific symbols assist in logical thinking. Many youngsters find these symbols difficult to understand since they are not used on a daily basis. An interactive educational tool designed for learning science may be useful in resolving this problem [1, 2, 3].

The periodic table is an important set of scientific symbols for scientific understanding, not commonly used in everyday life. The periodic table not only lists the symbols but also describes the relationships between chemical elements. The table is sequenced by atomic number, and membership of a group indicates the distribution of electrons for each atom. The periodic table appears in a variety of scholastic materials such as textbooks being used in junior high schools in Japan. Many types of educational tool for learning the periodic table have been proposed [4,5]. These previous tools encouraged students to independently memorize the symbol of each chemical element. These tools did not provide the opportunity to discover the relationships between chemical elements. For an educational tool, we focus on a 3D periodic chart that is a type of periodic table. A 3D periodic chart maps the chemical elements onto the 3D space. As the 3D periodic chart can be scanned from any viewpoint, a student is encouraged to actively learn the relationships between chemical elements.

In this study, we propose a NEO GAME involving a *sugoroku* game and a 3D periodic chart (i.e., *periodic-sugoroku*) as an appropriate educational tool. *Sugoroku* is a Japanese board game similar to *Parcheesi* or *Monopoly*. In Japan, educational tools based on the *sugoroku* game have already been proposed [6, 7]. Through the use of such a proposed tool, students can actively learn the periodic table while enjoying a *sugoroku* game.

2. Periodic-sugoroku

2.1 Overview of periodic-sugoroku

Learning the periodic table requires remembering both the names and values of the chemical elements. It is also important to understand the relationship between each chemical element. The educational tool should encourage students to perform three activities, as follows:

- observe the periodic table
- understand the value of each chemical element
- understand the position of each chemical element

In this study, we focused on *sugoroku* game in order to provide these educational effects. In *Sugoroku* game, players are required to place a game-piece onto a board containing many panels. Players then move these game-pieces according to a set of rules. Generally, the rule for moving a game-piece requires players to roll a die toward a goal-panel on the game-board.

In order to encourage students to observe and understand each chemical element, we employed a 3D periodic chart of Elemen-touch [8]. Elemen-touch is a one of periodic table, which places each chemical element along a spiral line on the 3D space. In contrast to the traditional 2D layout, Elemen-touch places each chemical element continuously around a 3D board. This enables students to effectively describe the relationship between each chemical element.

In this study's proposed *periodic-sugoroku*, each panel on the Elemen-touch game-board represents a chemical element. Players are able to move game-pieces by using playing cards instead of dice. Furthermore, the board does not contain a goal panel. Thus, players are able to move game-pieces to obtain scores when selecting chemical elements.

2.2 Periodic-sugoroku rules

Figure 1 shows the tools involved in this study's proposed *periodic-sugoroku*. Players use a tablet board (**Fig. 1.** (a)), playing cards (**Fig. 1.** (b)), element-cards (**Fig. 1.** (c)), and assistant-tablets (**Fig. 1.** (d)). One tablet board is shared among all players. The tablet board displays a 3D periodic chart as a gaming board through the use of computer graphics in addition to the position of each player's game-piece. Each player also has an assistant-tablet. The assistant-tablet shows all panels that the player is able to reach with their game-piece according to the combination of playing cards they possess.

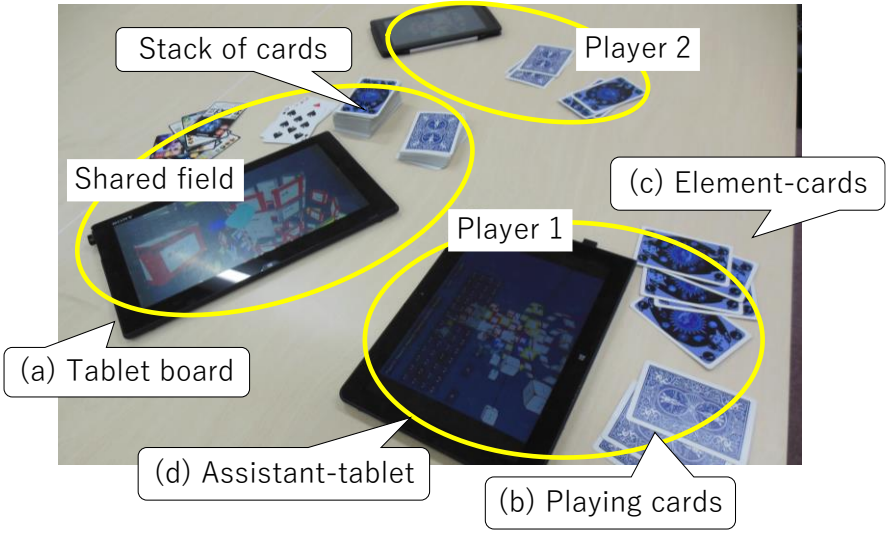

Fig. 1. *Periodic-sugoroku* game tools

Table 1. shows the *periodic-sugoroku* rules. In this game, each chemical element panel is associated with points matching the value of the chemical element. A noble-metal element contains 8 points, while rare-earth elements contain 4 points, rare-metal elements contain 2 points, and other common elements contain 1 point.

At the beginning of each game, 5 element-cards and 3 playing cards are dealt to each player. Player game-pieces are then placed on the Hydrogen panel, which contains the atomic number 1. Players are able to move game-pieces according to the sum of their playing cards by playing one element-card. When the color of the playing card is black, it is calculated as a positive number. Otherwise, the color of the playing card is red, which is calculated as a negative number. When the player reaches a panel and is in possession of an element-card matching that panel, they obtain the points associated with that chemical element. When a player obtains a point, they are able to draw 2 element-cards.

In addition, if a player plays an element-card as an extra cost, they are able to move their game-piece to another element belonging to the same group. When a player reaches a panel that is occupied by another player's game-piece, these players exchange all element-cards. When the stack of element-cards is depleted, the game is finished. At the end of the game, the player with the highest score is the winner.

Table 1. *Periodic-sugoroku* rules

Tools	Periodic table, game-pieces, playing card, element-card
Initializing	Deal 5 element-cards and 3 playing cards. All game-pieces are placed on the Hydrogen panel.
1. Point of element	Noble metal elements contain 8 points. Rare-earth elements contain 4 points. Rare-metal elements contain 2 points. Other common elements contain 1 point.
2. Score	When a player reaches a panel and is in possession of an element-card matching the panel, they obtain the points associated with the element.
3. Cost to move	Pay 1 element-card.
4. Destination	Move a game-piece according to the sum of the playing cards.
5. Move to same group	If a player plays an element-card as an extra cost, the player can move a piece to another element panel of the same group.
6. Exchange element-cards	When the player obtains a point, they are able to draw 2 element cards.
7. Extra-element-card	When a player reaches a panel that is occupied by another player's game-piece, these players exchange all element cards.
8. Winner	At the end of the game, the player with the highest score is the winner.

According to these rules, since players are able to move gamepieces through a combination of playing cards, they must strategically decide on its destination. This rule encourages players to observe the position of the chemical elements while understanding their values.

2.3 Periodic-sugoroku software

Element-touch is a 3D periodic chart on which the chemical elements are spirally positioned in a 3D space. In order to play *sugoroku* using this 3D periodic chart, each player much share information regarding all game-pieces. Players must also observe the 3D periodic chart from their own viewpoints. We therefore developed software for *periodic-sugoroku* using virtual reality and networking technology.

Figure 2 and **Fig. 3.** show the three software devices used in *periodic-sugoroku*. The first device involves a board-app that is utilized on a tablet board (**Fig. 2.** (a)). This board-app provides a 3D periodic chart that is used as a *sugoroku* board. The board-app can also display all game-pieces. Players share the board-app to move their game-pieces.

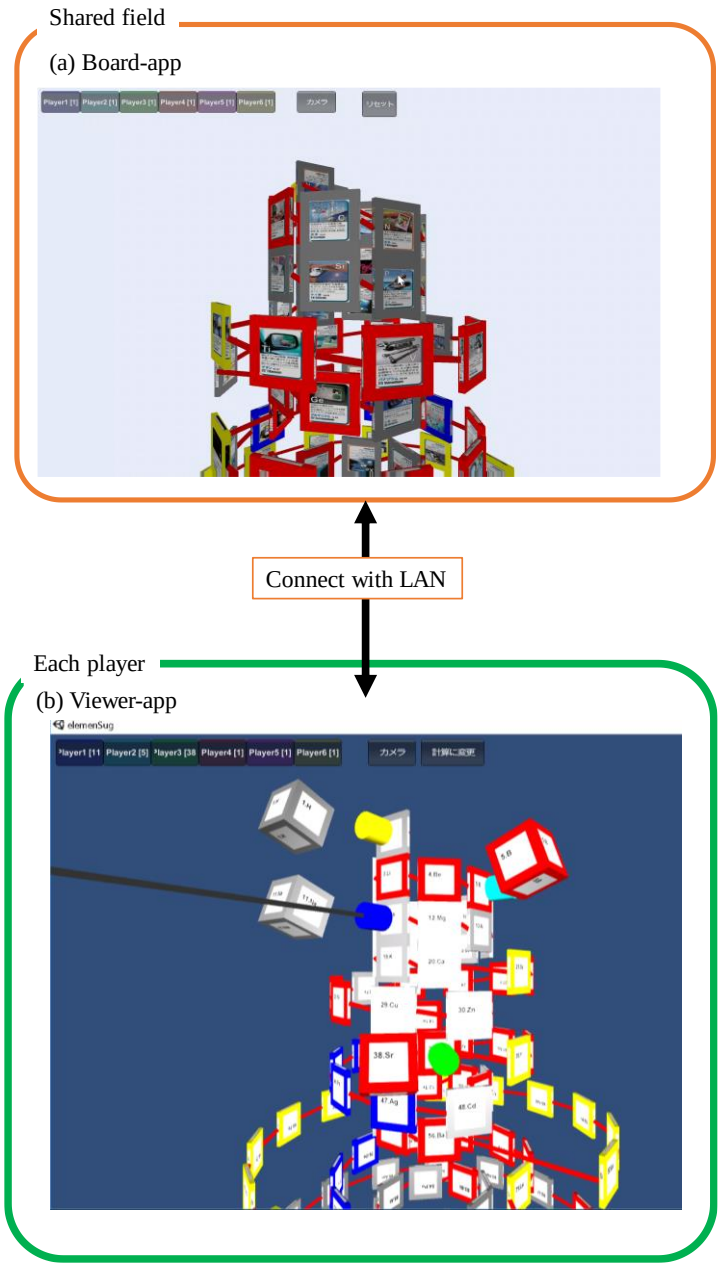

Fig. 2. Board-app and Viewer-app of *Peridoic-sugoroku* software

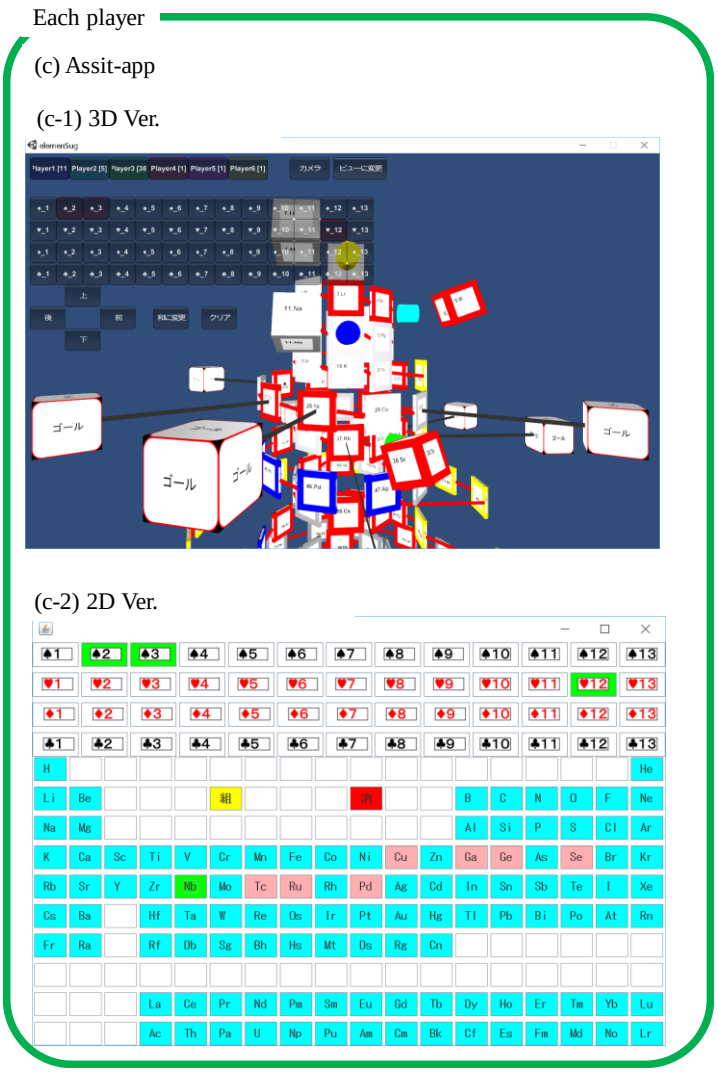

Fig. 3. Assist-app of *Periodic-sugoroku* software

A viewer-app (**Fig. 2.** (b)) works on each assistant-tablet. Each player can observe the 3D periodic chart using their own viewer-app. The board-app and viewer-app are connected through a local area network (LAN). The movement of a game-piece on the board-app is sent to the viewer-app; each viewer-app shows all game-pieces.

By using both the board-app and viewer-app, players are able to share the position of all game-pieces and observe the 3D periodic chart from a free viewpoint. These functions enable players to strategically plan.

An assist-app (**Fig. 3.**) works on the assistant-tablet. Two versions of assist-app, 3D version (c-1) and 2D version (c-2), were developed. The assist-app can obtain all destinations from all playing card combinations. The assist-app reduces the time taken to calculate destinations. Players are therefore able to concentrate on observing the 3D periodic chart while developing strategies to obtain high scores.

3. Experiment

In order to evaluate this study's *periodic-sugoroku*, a total of 16 participants played the game. After playing the game, the participants answered a questionnaire. In this experiment, we used one Windows laptop PC as a tablet board in addition to three Windows laptop PCs and one Android tablet PC that served as assistant-tablets. This experiment proceeded according to the following four steps:

1. Providing instructions on using the tablet board and assistant-tablets
2. Providing the rules for *periodic-sugoroku*
   - Overview of rules
   - Tutorial
   - Practice play (10 min.)
3. Playing *periodic-sugoroku*
4. Answering the questionnaire

Table 2. shows the questionnaire. Questions Q1 to Q6 concerned participant-characteristics, while questions Q7 to Q19 were about *periodic-sugoroku*, and Q20 was a general open-ended question.

This experiment was conducted three times. Different participants played *periodic-sugoroku* in each experiment. In the third round, participants played *periodic-sugoroku* in groups of two. We also provided ``How to play'' information so all participants were able to understand the rules.

Table 2. Questionnaire

Questionair of Periodic-sugoroku game Day: Month:
About your property
Q1. SEX Age : ( )
Q3. Have you ever taken a chemistry class? [YES / NO]
Q4. How many times did you play periodic-sugorokou?
About 3D periodic chart
Q5. Do you know that there are many kinds of periodic tables?
Q6. Do you want to use or learn about 3d periodic charts?
About your awareness after playing a game of periodic-sugoroku
Q7. Were you interested in the periodic table before playing periodic-sugoroku?
Q8. Did you gain interest in the periodic table?
Q9. Do you think that you want to use or learn the periodic table?
Q10. Did you gain interest in rare-earth or rare-metals?
Q11. Did you learn about elements you did not know about before?
Q12. Did you consider the relationship between each element?
Q13. Do you think you can learn the periodic table by playing periodic-sugoroku?
About periodic-sugoroku
Q14. Is it easy to remember the rules of periodic-sugoroku?
Q15. How was the usability of the board-app?
Q16. How was the usability of the viewer-app?
Q17. How was the usability of the assist-app?
Q18. Do you want to play periodic-sugoroku again?
Q19. Did you enjoy the game?
Q20. Free comment

Note: In the experiment, the questionnaire was written in Japanese.

Note: Participants were required to mark 1 to 5 to answer each Q5 to Q19.

(1. Strongly disagree, 2. Disagree, 3. Neither agree nor disagree, 4. Agree, 5. Strongly agree)

4. Results and discussion

The average play time was 40 minutes. At the beginning of the game, we received inquiries about the rules from some participants. Almost all players understood the rules and were able to play smoothly. Figure 4 shows the results of the questionnaire. The horizontal line indicates question number while the vertical line indicates score.

The results for Q7 (i.e., Were you interested in the periodic table before playing *periodic-sugoroku*?) indicated that not all participants were interested in the periodic table prior to playing the game. However, each median for Q8 to Q10 (i.e., Questions about interest in the periodic table after playing *periodic-sugoroku*) was either 3 or 4 points. These results indicate that *periodic-sugoroku* can attract participants to the periodic table.

The median of Q11 (i.e., Did you feel that you gained knowledge about the periodic table?) indicated a high score (5 points). On the other hand, the median of Q12 (i.e., Did you consider the relationship between each element?) was not high (2.5 points).

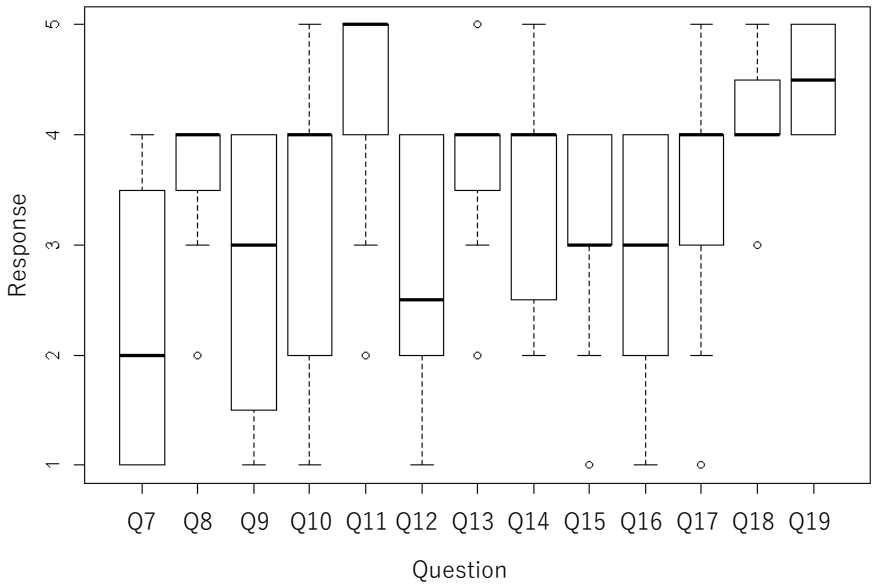

Fig. 4. Experimental results

Each median for Q13, Q18, and Q19 (i.e., Questions about *periodic-sugoroku* impressions) indicated high scores. These results indicate that many participants gave positive answers and wished to play *periodic-sugoroku* again.

In order to discuss the educational effect of the *periodic-sugoroku*, we obtained a correlation matrix of answers. Table 3. shows the correlation scores between each question and it also shows the results of the test for no correlation. There was a significant correlation ($p<0.05$) between Q12 through Q16 and Q15 through Q17 and the correlation scores were high (they are indicated by rectangular areas on the table). Q12 to Q13 involved interest in and understanding of the periodic table. Q14 to Q17 were questions regarding the operation of the *periodic-sugoroku* game.

The answer of Q11 shows that the proposed *periodic-sugoroku* can provide an opportunity to study a chemical element which the player has not known. The obtained correlation matrix indicates that participants who were able to proficiently use the assistant-tablet tended to be attracted to the periodic table through *periodic-sugoroku*.

Table 3. Correlation score

p<0.05, ** p<0.01)

	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19
Q7	1.00												
Q8	0.33	1.00											
Q9	**0.68****	0.32	1.00										
Q10	0.33	-0.15	**0.44**	1.00									
Q11	**-0.50**	-0.02	-0.13	-0.15	1.00								
Q12	-0.03	**0.42**	-0.15	-0.29	-0.09	1.00							
Q13	-0.03	0.33	0.10	-0.35	0.16	**0.70****	1.00						
Q14	0.39	-0.02	0.26	0.29	-0.25	-0.30	-0.15	1.00					
Q15	-0.02	0.17	0.15	-0.32	-0.03	**0.58***	**0.59***	-0.27	1.00				
Q16	0.13	0.52 *	0.09	**-0.45**	0.03	**0.63****	**0.57***	-0.22	**0.79****	1.00			
Q17	0.26	0.13	0.23	-0.09	0.03	0.40	**0.55***	-0.44	**0.42**	**0.42**	1.00		
Q18	-0.15	-0.07	0.15	-0.04	0.27	-0.04	0.17	0.30	-0.14	0.01	-0.09	1.00	
Q19	-0.16	0.32	-0.05	-0.10	**0.44**	-0.10	0.00	**0.44**	0.08	0.19	**-0.44**	0.00	1.00

5. Conclusions

In this study, we proposed a *periodic-sugoroku* game for learning the chemical elements. During the game, each player was required to move their game-piece by summing playing cards. The winner was the player with the highest score at the end of the game. In order to play the game, we developed a board-app, view-app, and assist-app.

A total of 16 players answered a questionnaire after playing so that we could assess the game. According to the questionnaire results, many participants positively evaluated the game and wished to play it again. Participants who were able to proficiently use the assistant-tablet tended to be attracted to the periodic table through *periodic-sugoroku*.

Future study requires improving the educational functions of the game, including the addition of a debriefing feature for the playing log.

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