Learning Support Game System for Sustainable Development Goals Education: Effects of Improved User Interface on Satoyama Forest Management Learning

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Abstract: Educational efforts focused on biodiversity and forest environmental conservation have become increasingly important, given the objective of achieving the sustainable development goals established by the United Nations. In Japan, Satochi-satoyama is a place to learn about biodiversity and forest environmental conservation. However, an increasing number of forests cannot be maintained due to changes in the industrial structure and population decline. Furthermore, the harmony between people and nature is being lost. Therefore, it is necessary to learn about the management of Satochi-satoyama. Experiential learning focused on field surveys has been conducted as a means of teaching Satoyama management. However, it is difficult for learners to develop a true understanding via this approach because the Satoyama vegetation succession occurs on a large time scale. Numerous simulation games have been developed to teach Satoyama vegetation successions and management methods using Satochi-satoyama as a theme. The authors are currently improving one such game, called the "Satoyama management game". In this paper, we describe the game improvements we have made so far. In addition, we discuss an experiment conducted using the improved version Satoyama management game and present its results.

1 INTRODUCTION

In recent years, the importance of educational efforts focused on biodiversity and forest environmental conservation has increased, in the interest of achieving the sustainable development goals established in September 2015 (United Nations, 2015).

In Japan, Satochi-satoyama is a place to learn about forest biodiversity and conservation. Satochi-satoyama is an area consisting of farmlands, irrigation ponds, secondary forest, plantation forest, and grasslands around human settlements. The environments of Satochi-satoyama have been formed through various human interventions. Due to the dynamic and mosaic utilization of land and cyclic resource use, a rich culture that coexists with nature while enjoying a variety of ecosystem services has been created. However, an increasing number of forests cannot be maintained due to changes in the industrial structure and population decline. Therefore, the harmony between people and nature is being lost (Ministry of the Environment, Government of Japan, 2010). For these reasons, it is necessary to learn about the management of Satochi-satoyama.

Management methods for Satoyama are taught through experiential learning via field surveys. However, experiential learning has some challenges. Specifically, the effects of management methods implemented by humans cannot be visualized immediately, as vegetation successions in Satoyama occur on a time scale of several decades or hundreds of years. Therefore, for example, even if an attempt is made at pest control through experiential learning, it is impossible to observe the impacts of Satoyama and difficult to achieve a realistic understanding.

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Various simulation games have been developed thus far to teach Satoyama vegetation successions and management methods. In a simulation game, the learner can actually experience an event even if it occurs on a large time scale. Also, using game as learning support is known to be an effective tool for learning (Prensky, 2003) (Calderón, A., & Ruiz, M., 2014).

Deguchi et al. (2010, 2012) developed a digital vegetation succession game called Digital SUGOROKU for learning vegetation successions. This was a sugoroku-type board game using touch panel and display.

Adachi et al. (2013), Nakayama et al. (2014), and Yoshida et al. (2015) developed a life-size board game for vegetation succession learning called Human SUGOROKU, which utilizes a full-body interaction system. This game was a full body interaction system.

Kawaguchi et al. (2017, 2018) developed a Satoyama management game in which learners become Satoyama managers to learn Satoyama management methods and vegetation successions. However, the Satoyama management game developed by Kawaguchi et al. (2018) had two major improvements. The authors improved the user interface, one of the two major improvements, and developed new Satoyama management game. Then, in order to evaluate the new Satoyama management game, an experiment for elementary school students was conducted. As a result of the experiment, we were able to suggest the effectiveness of the new Satoyama management game.

The remainder of this paper is organized as follows. Section 2 discusses the points requiring improvement in the Satoyama management game developed by Kawaguchi et al. (2018) and the improvements made by the authors thus far. Section 3 describes the experiments performed, in which elementary school students experienced the improved Satoyama management game, and Section 4 presents the results. Finally, Section 5 summarizes the main conclusions.

2 SATOYAMA FOREST MANAGEMENT GAME

2.1 Overview of the Game

The Satoyama management game allows learners to learn Satoyama management and vegetation successions while experiencing Satoyama management. In the game, learners experience events that occur on time scales of decades or hundreds of years, which humans cannot experience. Figure 1 shows the play screen of the Satoyama management game developed by Kawaguchi et al. (2018).

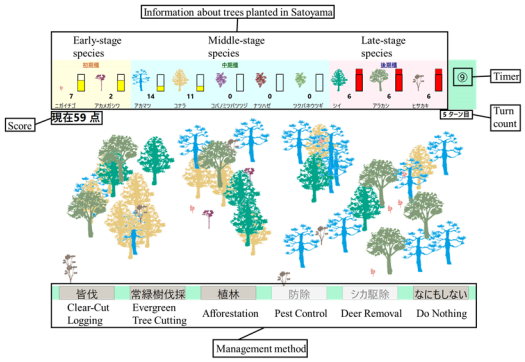

Figure 1: Play screen of Satoyama management game by Kawaguchi et al. (2018)

The learner manages Satoyama using one of the following six management methods.

- Clear-Cut Logging
- Evergreen Tree Cutting
- Afforestation
- Pest Control
- Deer Removal
- Do Nothing

The learner can choose a management method for 20 turns and experience about 300 years of Satoyama management.

In the game, there are early-, middle-, and late-stage type of tree species. The trees included in each type are as follows.

- Early-stage species: *Rubus microphyllus, Mallotus japonicas*
- Middle-stage species: *Pinus densiflora*, *Quercus serrata*, *Rhododendron reticulatum*, *Vaccinium oldhamii*, *Abelia spathulate*
- Late-stage species: *Castanopsis spp.*, *Quercus glauca*, *Eurya japonica*

Each tree has different characteristics. In the game, the tree height was made different for each type.

The center of the game screen depicts, the situation in Satoyama that the player manages. The number of trees growing is displayed numerically at the top of the screen. Next to this number, a meter is used to indicate whether the number of trees is large or small. The number of trees increases and decreases when the learner manages or when the growing trees interact with each other.

The learner proceeds through the game with reference to the score displayed in the upper left part of the game screen. In this game, the ideal number of trees to be vegetated in Satoyama is decided. If the ideal number of trees is approached, the score will

increase. The learner proceeds with Satoyama management considering the effects of the management method that he / she performs for 20 turns and the influence of the relationship between the trees. After 20 turns have been completed, the player can know his/her Satoyama management score.

By repeating this game, users can learn Satoyama management and vegetation successions.

2.2 Improvement of the Game

Two major improvements were made to this game. The first is related to the user interface, and the second is related to the number of Satoyama types supported. Each is described in the following sections.

2.2.1 User Interface

The user interface could be improved in several regards.

First, this game has no tutorial. In order for learners to experience the game, it is necessary to explain in advance how to play the game. If a tutorial is created, learners will be able to experience the game even if no one is nearby who knows how to play.

Next is the representation of time in the game. In the developed game, the time of each turn is counted in numbers per s in the upper right. However, few learners notice the time, because learners often look at the growing trees and management methods, and do not notice the count displayed in the upper right.

In addition, the game should enable users to experience a time scale of decades to hundreds of years, but there is no part that indicates the time scale, making it impossible to determine whether a long time has passed just by looking at the current number of turns.

Finally, there is little information that facilitates learning during the game experience. By repeating the game, learners can understand which trees the management practices will influence. However, in order for learners to learn, it is necessary for them to be aware of the rules of the game. Consequently, learners who are unaware of the rules may not be able to learn the intended objectives. In order to reduce this issue, the amount of information that facilitates learning during the game should be increased.

2.2.2 Number of Supported Satoyama Types

The Satoyama management game developed by Kawaguchi et al. (2018) is only compatible with one of the typical Satoyama types in Japan, although there are four in total.

- *Quercus mongolica* forest in northern Honshu, Japan
- *Quercus serrata* forest from eastern Honshu to the Sea of Japan side of the Chugoku region
- *Pinus densiflora* forest in western Japan
- *Castanopsis spp*. forest in southern Japan

The current game pertains to the *Pinus densiflora* forest in western Japan.

Satoyama vegetation types and management methods differ depending on the region. Therefore, if a Satoyama management game can be developed that supports all of these types, learners will be able to acquire more knowledge than they can at present.

2.3 Improvements Made to Date

In Section 2.2, we described the areas requiring improvement in the Satoyama management game. The authors are currently implementing improvements in these areas. We began by focusing on the user interface. The following subsections describe the improvements that have been made so far.

2.3.1 Create Tutorial

We created a tutorial that did not exist before. The tutorial can be selected on the screen before the game starts. The tutorial teaches that Satoyama will not be in good condition unless management is performed by a person. It also tells learners how to proceed with the game and that there is information in the game that will help learners with the game.

2.3.2 Screen Design

Figure 2 shows the Satoyama management game play screen after the improvements, which changed many aspects of the game design. These changes will be addressed individually in this section.

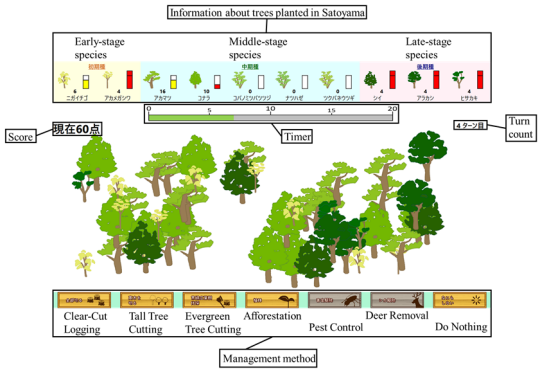

Figure 2: Play screen of improved Satoyama management game.

Figure 3: Tree picture display.

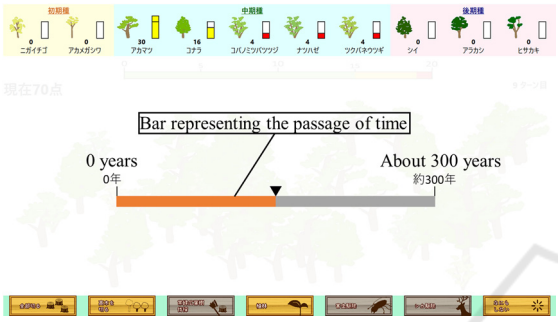

Figure 4: Representation the passage of time.

First, the tree illustrations were modified. In conventional games, trees are represented by silhouettes, and the colors of the trees are unrealistic, making the game screen different from the actual appearance of a mountain. To address this issue, the colors of the tree illustrations were made closer to those of the actual trees, making it easier to imagine the trees growing in the mountains. Different color depths were used for early-, middle-, and late-stage species, enabling the three types to be identified by color depth.

The management method buttons were also changed. In conventional games, only letters are presented, so learners who do not understand their meanings may not be able to understand the management method. Therefore, we added illustrations next to the letters to help learners understand the effects of the management methods. In addition, “Tall Tree Cutting” was added as a management method. Since the inclusion of additional Satoyama types in the game is under consideration, a management method used for those Satoyama types was added.

As a new function, when the user hovers over each tree in the upper part of the screen, a picture of the actual tree appears, as shown in Figure 3. In this picture, information that is important for the game is displayed. Checking the information provided in the pictures will help learners find appropriate Satoyama management methods.

In addition, the meaning of the meter that expresses the number of trees growing was changed, as one piece of information that helps the game progress. The early- and late-stage species appear in red when the ideal number of trees is exceeded, and the middle-stage species appear in red when the number of trees is much smaller than the ideal number. This approach was chosen because ideally Satoyama has more middle-stage species than early- and late-stage species. If learners are aware of this information, they will be able to discern the appropriateness of the current state of Satoyama.

2.3.3 Representation of Time

We also improved the representation of time. The management method selection time of 20 s per turn is indicated by a bar, as shown in the center of Figure 2. The color of the bar changes over time.

In addition, improvements were made to clarify the passage of time over 300 years. When a management method is selected at each turn, a bar indicating that time has passed is displayed, as shown in Figure 4. As the turn progresses, the black triangle moves, enabling learners to be aware of the passage of time.

3 EXPERIMENTAL DESIGN AND ASSESSMENT METHOD

An experiment was performed using the Satoyama management game with the improved user interface, as described below. The experiment was conducted over four days from November 19 to November 22, 2019. The participants in this experiment were 31 children in Grades 5 and 6 at an elementary school attached to a national university. Volunteers were recruited at the school.

3.1 Aim

To clarify how the participants experienced the Satoyama management game, we assessed game immersion and understanding of the controls and screen changes. Moreover, we assessed how the participants felt and what they learned from the tutorial that was added to the game and the elements that received major updates, specifically, how time is expressed and the screen design.

3.2 Protocol

The participants received pre-game instructions and played one round of the Satoyama management game

(10 min) during a morning break and five rounds during the lunch break (15 min), for a total of six rounds. After school on the same day, the participant simultaneously filled out a questionnaire related to the questions described in Section 3.4.

3.3 Questions

To assess immersion, we created five items to measure to what extent the participants were absorbed in the game, such as "I was absorbed in managing the Satoyama when playing the game." To assess understanding of the controls and screen changes, we created six items, such as "I knew where to press and what the response would be when progressing through the game". To assess the effect of the newly added tutorial, we created four items, such as "I thought the tutorial in the Satoyama management game was easy to understand." To assess how time is expressed, we used four items, such as "I could imagine how long the Satoyama plants' changes would take in reality." To assess the screen design, we utilized eight items, such as "I could imagine how the real trees look by seeing the illustrations of the trees in the game." In total, there were 27 question items.

3.4 Analytical Method

We asked the participants to respond to each question item on a seven-point scale. We classified the responses as positive for "Strongly agree," "Agree," and "Slightly agree," and as neutral or negative for "Neither," "Slightly disagree," "Disagree," and "Strongly disagree." We aggregated the frequency of each response for every question, conducting Fisher's exact test using a 1×2 contingency table with an uneven population ratio. We defined the population ratio of positive responses as the rate at which any of the three positive responses out of the seven levels was received; we also defined the population ratio of neutral and negative responses as the rate at which the four neutral or negative responses out of the seven levels were received. We compared the values for each question item and conducted an exact binomial test (one-sided "greater"), designating $p < 0.01$ as indicating a significant deviation.

4 ASSESSMENT RESULTS

4.1 Assessment of Immersion in the Game

Table 1 summarizes the results of the assessment of immersion in the game. We found a significant deviation ($p < 0.01$) in the results for all items with regard to immersion.

4.2 Assessment of Understanding of Controls and Screen Changes

Table 2 summarizes the results of the assessment of understanding of the controls and screen changes. We found a significant deviation ($p < 0.01$) in the results of all items with regard to understanding controls and screen changes.

4.3 Survey of the Game Tutorial Effect

Table 3 summarizes the results of the assessment of the effect of the game tutorial. We found a significant deviation ($p < 0.01$) in the results for all items with regard to the effect of the tutorial.

Table 1: Questions about immersion in the Satoyama management game.

(Unit: number of persons)

	Question item	7	6	5	4	3	2	1	Pos.	Neut. Neg.
1-1	The *Satoyama* management game was fun.**	30	1	0	0	0	0	0	31	0
1-2	I was absorbed in managing the *Satoyama* when playing the game.**	20	8	3	0	0	0	0	31	0
1-3	I was happy when my score increased.**	24	6	1	0	0	0	0	31	0
1-4	I was frustrated when my score decreased.**	14	9	8	0	0	0	0	31	0
1-5	I was happy when the change I expected happened after pressing a *Satoyama* management command.**	18	9	3	1	0	0	0	30	1

N = 31.**$p < 0.01$

Strongly agree: 7; Agree: 6; Slightly agree: 5; Neither: 4; Slightly disagree: 3; Disagree: 2; Strongly disagree: 1

4.4 Survey of How Time is Experienced while Playing the Game

Table 4 summarizes the results of the assessment of how time is experienced while playing the game. We found a significant deviation ($p < 0.01$) in the results for all items with regard to the experience of time.

Table 2: Results of the assessment of understanding the controls and screen changes when playing the Satoyama management game.

(Unit: number of persons)

	Question item	7	6	5	4	3	2	1	Pos.	Neut. Neg.
2-1	The *Satoyama* management game was easy to control.**	12	17	2	0	0	0	0	31	0
2-2	I knew where to press and what the response would be when progressing through the game.**	20	6	3	2	0	0	0	29	2
2-3	I knew the meaning of the color changes of the status bar at the top of the screen.**	21	6	4	0	0	0	0	31	0
2-4	I knew what the changing numbers below and to the left of the top-screen status bar meant.**	15	7	5	2	1	1	0	27	4
2-5	It was easy to see that deer had appeared in the *Satoyama* by looking at the screen of the *Satoyama* management game.**	15	6	4	2	2	1	1	25	6
2-6	It was easy to see that bugs had appeared in the *Satoyama* by looking at the screen of the *Satoyama* management game.**	16	6	2	2	3	2	0	24	7

N = 31. $^{**}p < 0.01$

Strongly agree: 7; Agree: 6; Slightly agree: 5; Neither: 4; Slightly disagree: 3; Disagree: 2; Strongly disagree:1

Table 3: Results of the assessment of the effectiveness of the Satoyama management game tutorial.

(Unit: number of persons)

	Question item	7	6	5	4	3	2	1	Pos.	Neut. Neg.
3-1	I thought the tutorial in the *Satoyama* management game was easy to understand.**	15	13	3	0	0	0	0	31	0
3-2	I felt like playing the game when I watched he *Satoyama* management game's tutorial.**	23	6	1	1	0	0	0	30	1
3-3	I knew what to do in the game by watching the *Satoyama* management game's tutorial.**	18	10	2	1	0	0	0	30	1
3-4	I knew what I need to think about to increase the score of the *Satoyama* by watching the *Satoyama* management game's tutorial.**	11	8	5	5	2	0	0	24	7

N = 31.$^{**}p < 0.01$

Strongly agree: 7; Agree: 6; Slightly agree: 5; Neither: 4; Slightly disagree: 3; Disagree: 2; Strongly disagree:1

Table 4: Results of the assessment of how time is experienced while playing the Satoyama management game.

(Unit: number of persons)

	Question item	7	6	5	4	3	2	1	Pos.	Neut. Neg.
4-1	It was easy to understand how much time was left for entering commands.**	9	10	6	2	4	0	0	25	6
4-2	It was easy to understand how much time passed in the game after I had entered a command until the *Satoyama* changed to the next status.**	10	10	6	1	2	2	0	26	5
4-3	It was easy to understand how much time passed inside the *Satoyama* management game.**	12	6	9	1	3	0	0	27	4
4-4	I could imagine how long the *Satoyama* plants' changes would take in reality.**	12	5	7	3	3	1	0	24	7

N = 31.**$p < 0.01$

Strongly agree: 7; Agree: 6; Slightly agree: 5; Neither: 4; Slightly disagree: 3; Disagree: 2; Strongly disagree:1

Table 5: Results of the assessment of the Satoyama management game's screen design.

(Unit: number of persons)

	Question item	7	6	5	4	3	2	1	Pos.	Neut. Neg.
5-1	It was easy to understand the picture of the square command (management technique) button at the bottom of the screen.**	23	7	1	0	0	0	0	31	0
5-2	It was easy to distinguish between early, middle, and late successional species by looking at the illustrations of the trees.**	14	10	5	0	1	1	0	29	2
5-3	It was easy to distinguish between high and low trees by looking at the illustrations of the trees.**	12	8	5	3	2	1	0	25	6
5-4	It was easy to tell how many of each tree was in the *Satoyama* by looking at the game screen.**	13	10	5	2	1	0	0	28	3
5-5	I felt like I was managing a real forest (*Satoyama*) while playing the game.**	16	9	5	1	0	0	0	30	1
5-6	I could imagine how the real trees look by seeing the illustrations of the trees in the game.**	11	10	8	2	0	0	0	29	2
5-7	I could imagine how the real trees look by seeing the photos of trees coming out of the top bar.**	19	7	4	0	1	0	0	30	1
5-8	It was easy to tell whether the *Satoyama* was doing well or poorly by looking at the *Satoyama* management game's screen.**	20	4	6	1	0	0	0	30	1

N = 31.**$p < 0.01$

Strongly agree: 7; Agree: 6; Slightly agree: 5; Neither: 4; Slightly disagree: 3; Disagree: 2; Strongly disagree:1

4.5 Survey of the Game's Screen Design

Table 5 summarizes the results of the assessment of the game screen design. We found a significant deviation (one-sided test for all items: $p < 0.01$) in the results for all items.

5 CONCLUSION AND FUTURE WORK

This paper describes the areas requiring improvement in the Satoyama management game developed by Kawaguchi et al. (2018) and the improvements made by the authors to address these issues thus far. Then, it discusses an experiment performed by elementary school students using the improved Satoyama management game. We evaluated five items. Significant differences were observed in all items. In other words, with the improvements implemented, it can be said that the Satoyama management game has become a more effective tool for learning Satoyama vegetation successions. However, only one of the two major improvements were improved in this paper.

In the future, the authors intend to implement the second improvement, increasing the number of Satoyama types supported by the game.

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