Rodrigo, M. M. T. et al. (Eds.) (2021). Proceedings of the 29th International Conference on Computers in Education. Asia-Pacific Society for Computers in Education

A Learning Game on the Structure of Arithmetic Story by Chained Sentence Integration

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Abstract: Problem-posing ability has a positive relationship with mathematics achievement and the understanding of the mathematical structure of problems. This study focuses on creating arithmetical stories as a sub-task of problem posing and proposes a game named "Tri-prop scrabble" as a learning environment based on a fusion method of learning and game. In the game, learners are expected to experience creating and comparing a variety of arithmetical stories by integrating simple sentences.

Keywords: Arithmetical word problem, learning game, fusion of learning and game

1. Introduction

A method of learning by posing problems rather than solving them is called "learning by problem-posing." Some researchers have reported a positive relationship between problem-posing ability and mathematics achievement (Silver and Cai, 1996; English, 1998) and the understanding of the mathematical structure of problems (Ellerton, 2015).

Monsakun, a learning environment for posing arithmetical word problems by sentence integration, has been developed, in which learners can learn the structure of arithmetical word problems (Hirashima et al., 2007). This system provides learners with some sentence cards (e.g., there are three apples) representing a proposition with a quantity, and learners select and assemble these cards to make an arithmetical word problem. Through this activity, Monsakun aims to encourage them to learn the structure of arithmetical stories. The use of Monsakun in elementary schools demonstrated its effectiveness (Hirashima et al., 2008).

In this study, we propose a learning game named "Tri-prop scrabble" designed based on a fusion method of learning and game (Umetsu 2002). Tri-prop scrabble is the fusion of Monsakun as learning and Scrabble (Scrabble, n.d.) as a game. As mentioned above, Monsakun is the learning environemt that requests learners to assemble an arithmetical word problem with sentence cards (one sentence card expresses one proposition). Scrabble is the game that requests players to assemble and concatenate words with letter cards. Tri-prop scrabble enables learners to experience creating and comparing a variety of arithmetical stories according to the situation. Because the activities in Tri-prop Scrabble are similar to the game activities in Scrabble in producing things by assembling and concatenating cards, it is expected that learners are also able to enjoy the learning activities in the same way with the original Scrabble.

2. Triplet Structure Model

A simple arithmetical word problem is a problem that can be solved with a single arithmetical operation. Arithmetical word problems can be formulated as consisting of two *existent sentence*s that express the existence of a quantity and a *relational sentence* that expresses the relationship between the two quantities (Hirashima et al., 2014). Any problems can be defined within a problem space where unknown facts can be derived from given facts with relations in a context (Milinković, 2015). Therefore,

a way to pose an arithmetical word problem is to make a valid arithmetical story with two existent sentences and a relational sentence and then to make them incomplete.

Whereas Monsakun asks learners to conduct both tasks at once, we focus on the former story-making task in this study. In each question on Monsakun, learners are required to pose the arithmetical word problem uniquely determined with the combination of the simple sentences given to the learner by the requirements on the formula and on the type of story. On the other hand, it is also possible to create multiple stories from a single simple-sentence. For example, with the simple-sentence "there are five apples," we can create all types of stories: combination, increase, decrease, comparisons. This study aims to realize an exercise to learn the mathematical structure of arithmetical stories by having learners examine the possibility of creating as many arithmetical stories as possible from a simple-sentence.

3. Tri-prop Scrabble

Tri-Prop Scrabble is a multi-player card game in which players connect simple-sentence cards to create questions in turn. As shown in Figure 1, like the word game Scrabble, players make stories by connecting sentence cards dealt to the players. The player who is first to shed their cards wins. The ends of cards allow to connect other simple-sentence cards, and players find a place where they can create an arithmetical story and make a story by taking out two of their own cards. This activity aims at learning the mathematical structure of arithmetical stories that are required to understand arithmetical word problems.

Figure 1. A play image of Tri-prop Scrabble.

The procedure of the Tri-Prop Scrabble is shown in Figure 2. In this exercise, players make the chain of arithmetical stories with the simple-sentence cards in their hands and compete in the number of stories they made. They can judge the correctness of their stories by scanning cards with Story AR checker. The last step shows the interface of Story AR checker. This system recognizes a story created as a sequence of cards in the real space by reading the simple-sentence cards with markers by the camera on the tablet. The system is developed using Vuforia that is an Augmented Reality SDK and Unity and C# as the development environment.

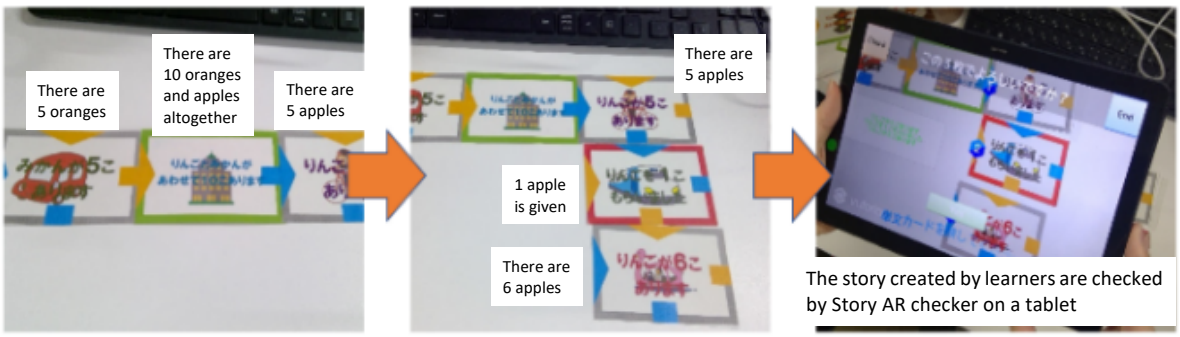

Figure 2. Procedure of playing the game.

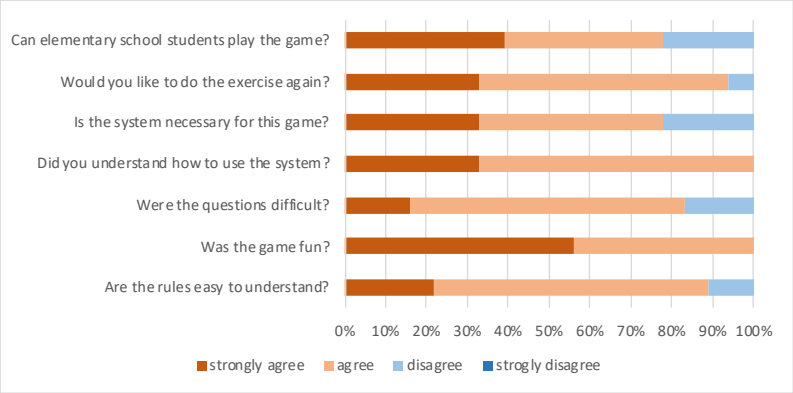

Figure 3. The result of the questionnaire.

4. Preliminary Use by High School Students

We conducted a preliminary feasibility study of the use of Tri-prop Scrabble with 18 female high school students. Although the primary target of Tri-prop scrabble is elementary school students, in this experiment, the subjects are high school students because they can make sure to solve arithmetical word problems, that is, they understand the structure of arithmetical stories. If they cannot accept the tasks required in the game, it is almost impossible for elementary school students to play the game.

The subjects were divided into groups of three. Each group played the game for 15 minutes. They made 8.17 stories per group. The questionnaire result in Figure 3 showed that they could easily understand the rules, enjoyed the exercises, and felt the proposed exercises could be carried out by elementary school students as long as the method and usage of the exercises are appropriately explained.

5. Conclusion

In this study, we proposed the game promoting exploratory making arithmetical stories as sentence-integration and developed the system Monsakun AR supporting the game with AR. The game requires the players to explore possible arithmetical stories with simple-sentences on the table and in their hands. Story AR checker recognizes the card with the camera and judges the validity of the stories the players make. The results of the preliminary use of the game with the system show the potential of the use by the elementary school students as the proper user. The future is to verify the learning effect of the proposed game further and to extend the game and the system to multiplication and division operations.

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