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A Case Study of Interactive Environment for Learning by Problem-posing Targeting Junior High School Students with Reading Disability

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Abstract: In this paper, we describe a case study of learning environment for problem-posing targeted as learners with reading disability. We have developed a learning environment for problem-posing as sentence integration that is different from usual problem-posing targeted as arithmetic word problem. In this exercise, a learner is required to select and arrange given simple sentence cards for posing problems. On the other hands, learners write problems from scratch in usual problem-posing. Because it is very difficult for learners with reading disability to write a sentence, they cannot exercise by usual problem-posing virtually even though a teacher would like to teach the arithmetic word problems to them through problem-posing exercise. However, several learners with reading disability are able to read a simple sentence. So, we assumed that these learners realize to exercise problem-posing by the problem-posing as sentence integration. Analysis of its practical use confirmed that it is possible for them not only to pose a problem but also to learn a structure of arithmetic word problem by using our learning environment.

Keywords: Problem-posing as sentence integration, arithmetic word problem, special classroom, reading disability

1. Introduction

A special classroom is dedicated to the education of students with special needs. This classroom often includes a small group of students with special needs. The special needs include learning disabilities, communication disorders, emotional and behavioral disorders, physical disabilities, and developmental disabilities. Teacher provides them an education that addresses their individual differences and needs. Many learner with learning disability includes one of learning disability called reading disability. It is very difficult for them to read and write a sentence. A teacher and several researchers teach them how to solve the arithmetic word problem as easily as possible (William, 2007; Jitendra and Hoff, 1996; Xin et al, 2005). For example, they explain a meaning of each sentence or divide a complex sentence into some simple sentences when they are solving the arithmetic word problem. Additionally, if the learner difficult to read the simple sentence, the teacher often explains the arithmetic word problem by using some picture in several school. Thus, it is hard for a teacher to teach the arithmetic word problems in special classroom.

Problem-posing is suggested as an effective way for improving learner's understanding of mathematical concepts and the development of mathematical thinking (English, 1998; Silver, 1997; Singer and Moscovici, 2008). In this exercise, a learner is given an assignment, and then, he/she is required to pose a problem by writing it from scratch. The teacher of special classroom would like to teach the arithmetic word problem by problem-posing if the learner can do it. However, learner with reading disability is not able to pose an arithmetic word problem because of their disability.

We have designed and developed a learning environment for posing an arithmetic word problem (Hirashima et al, 2007; Yamamoto et al, 2012, 2013, 2014). In this problem-posing, the learner is required to select and arrange a few sentences in order to pose the problem. These sentences are designed by structuralizing targeted problem. We call this exercise problem-posing as sentence integration. Its learning environment can assess the posed problem automatically and feedback the result of problem-posing in real-time. By using this learning environment, the learner can understand a problem structure to pose the problem. Actually, we have confirmed that the learner improved their understanding of problem structure after they have learned the arithmetic word problem by using our environment in regular class.

We assumed that the learner with reading disability can pose an arithmetic word problem and understands a structure of arithmetic word problem by using our learning environment if he/she is able to understand a simple sentence. The purpose of this research is to realize the learning of problem-posing in special classroom by using our learning environment. Previously, a teacher in special classroom requested us to use our learning environment in his class because he has same assumption. A result of this experimental use has suggested that the learners with reading disability who cannot exercise usual problem-posing could exercise the problem-posing by using our learning environment (Yamamoto et al, 2016). We don't find a research that the learner with reading disability realized to exercise problem-posing. However, there are only two subjects in this experimental use.

In this paper, we report a case study of our learning environment for a sixteen learners with intellectual disability who belongs to special classroom at junior high school in Hiroshima. A purpose of this paper is to verify an assumption that our learning environment realizes that the learner with reading disability can exercise problem-posing and understand the problem structure. A relation between the problem-posing as sentence integration and reading disability are explained in next section. Subsequently, we have described an error of problem-posing, kind of problems and a developed learning environment by problem posing called MONSAKUN Touch. Lastly, a procedure of case study of learning environment and its result are reported.

2. Problem-posing and Reading Disability

2.1 Problem-posing

We focused on an arithmetic word problem that can be solved by one-step addition or subtraction in this research. Figure 1 shows usual problem-posing of the arithmetic word problem. In this exercise, leaners are required to pose the problem that is satisfied a given assignment like calculation. Then, they pose the problem from scratch by writing sentence.

On the other hands, we have defined the problem-posing as sentence integration that required learners to pose the problem by selecting and arranging a three simple sentences from a given simple sentences in Figure 2. In this exercise, they need to read and understand each given sentences that consist of quantity, object and attribute. For example, in the first sentence of Figure 2, the quantity is "five". The object is "apple". The attribute is "There are" that expresses existence of quantity. We call this simple sentence the independent quantity sentence. The third sentence of Figure 2 has the attribute that is "altogether". This attribute expresses the relation between the quantity of apple and orange. This simple sentence called the relative quantity sentence. These simple sentences show the quantitative . concepts. In our research, the arithmetic word problem is expressed by three quantity sentences because the arithmetic word problem that can be solved one-step addition or subtraction consists of three quantities: operand, operant and result quantity. We call this model as triplet structure model (Hirashima et al, 2014). Therefore, if a learner is able to read and understand this concept, he/she can exercise the problem-posing as sentence integration.

Assignment: Pose problem that can be solved by "8-5".
Answer: There is one big tree. Tree has five apples and there are several oranges on other tree. A number of apples and oranges are eight. How many oranges are there?

Figure 1. Usual Problem Posing.

Assignment: Pose a problem that can be solved by "8-5" .

Answer:
- There are 5 apples.
- There are ? oranges.
- There are 8 apples and oranges altogether.

Dummy:
- There are 7 apples.
- There are ? bananas.
- 8 apples are eaten.

Given simple sentences

Figure 2. Problem-posing as Sentence Integration.

2.2 Relation between targeted reading disability and problem-posing as sentence integration

There are several learners with reading disability in special classroom. They need a long time to recognize each word more than regular learners. Moreover, it is known that most learners with reading disability cannot write a sentence correctly. Thus, they cannot exercise by usual problem-posing because of their disability.

So, the learner with reading disability often finds difficulty in reading sentence but several learners are able to read the simple quantity sentence. They are our targeting learner because the arithmetic word problem composed of three simple quantity sentences in triplet structure model. In other words, the problem-posing as sentence integration may provide a scaffold that provides the each simple sentence for learning by problem-posing. However, it is difficult for teacher to assess posed problems in real-time even if teacher use our method. Our learning environment solved this difficulty so that teacher and learner realize the problem-posing of arithmetic word problem by using information technology. We have already performed an experimental use in special classroom in which there are two targeted learners at elementary school. The results of the experimental use suggested that they are able to pose the problem and improve their ability for posing the arithmetic word problem that can be solved by one-step addition or subtraction. However, there are a few subjects in this experimental use. Therefore, we verify the realization of problem-posing as sentence integration for our targeted learners as additional experimental use so that anyone who understands the quantitative concepts are learn by problem-posing as sentence integration in special classroom.

3. Learning environment for problem posing as sentence integration

3.1 Exercise on Learning Environment

Functions for exercising the problem-posing as sentence integration targeted as the arithmetic word problem are implemented on a learning environment called MONSAKUN Touch (Yamamoto et al, 2016). MONSAKUN Touch runs on Android tablet. In this learning environment, the learner can select a level of assignment after login. If the level is selected, MONSAKUN Touch displays the main interface for problem posing that is shown in Figure 3. This interface presents an assignment of posing problem in upper right area, the group of given simple sentence cards in right area and the three blanks for setting selected sentence cards in center left area. The assignment shows the calculation and story. The learner poses the problem by selecting three simple sentence cards from given cards and arranging them in proper order. Given sentence cards are consists of both correct and dummy cards that leading to errors. If three blank is filled with three sentence cards, diagnosis button will be active. After the learner taps this button, MONSAKUN Touch diagnoses and generate a feedback his/her posed problem in real-time. Feedback consists of Flag Feedback that replies correct or incorrect and Pointing Hint that replies points of error (Vanlehn et al, 2005). The feedbacks are displayed by a sentence. If the learner finishes answering all assignment in selected level correctly, the interface for posing problem changes to the interface for selecting level.

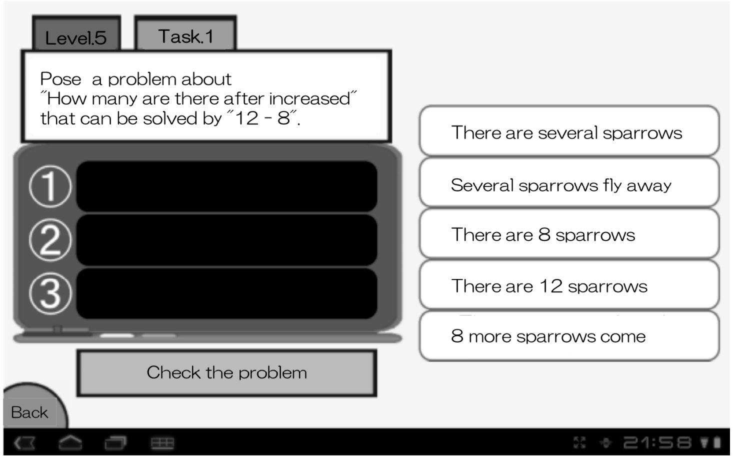

Figure 3. Main interface of MONSAKUN Touch.

3.2 Level of Assignment and Kind of Error

Table 1 shows a level of assignment on MONSAKUN Touch. A different of each level is a kind of posed problem, a given calculation and a given story. The story is divided into addition story and subtraction story. Addition story is usually expressed by increase story or combine story. Subtraction story is usually expressed by decrease story or comparison story. For example, the following story is decrease story.

{There are "?" apples. 2 apples are eaten. There are 3 apples.}

We are able to solve this problem by "3+2". We call this calculation for solving problems the calculation numerical relation. And then, the numerical relation of this problem expresses as the subtraction story that is "?-2=3". We call this calculation based on story the story numerical relation.

In above problem, story numerical relation and calculation numerical relation are deferent. We call this type of problem "reverse thinking problem". If story numerical relation and calculation numerical relation are same, then such problems are called "Forward thinking problem". Reverse thinking problem is much harder than forward thinking problem. The level of assignment is designed to be the step by step based on these definitions. The level one is easiest assignment in MONSAKUN Touch. The level two and three of assignment are difficult secondly because the learner is required to pose reverse thinking problem but indicated calculation is story numerical relation. The level four and five of assignment is most difficult assignment because the learning environment shows the learner to calculation numerical relation and the learner poses reverse thinking problem.

Table 1: Level of Assignment.

Level	Kind of posed problem	Given calculation	Given Story
1	Forward thinking problem	Story numerical relation	Combine, Increase, Decrease, Comparison
2	Reverse thinking problem	Story numerical relation	Combine, Increase
3	Reverse thinking problem	Story numerical relation	Decrease, Comparison
4	Reverse thinking problem	Calculation numerical relation	Combine, Increase
5	Reverse thinking problem	Calculation numerical relation	Decrease, Comparison
6	Random	Random	Random

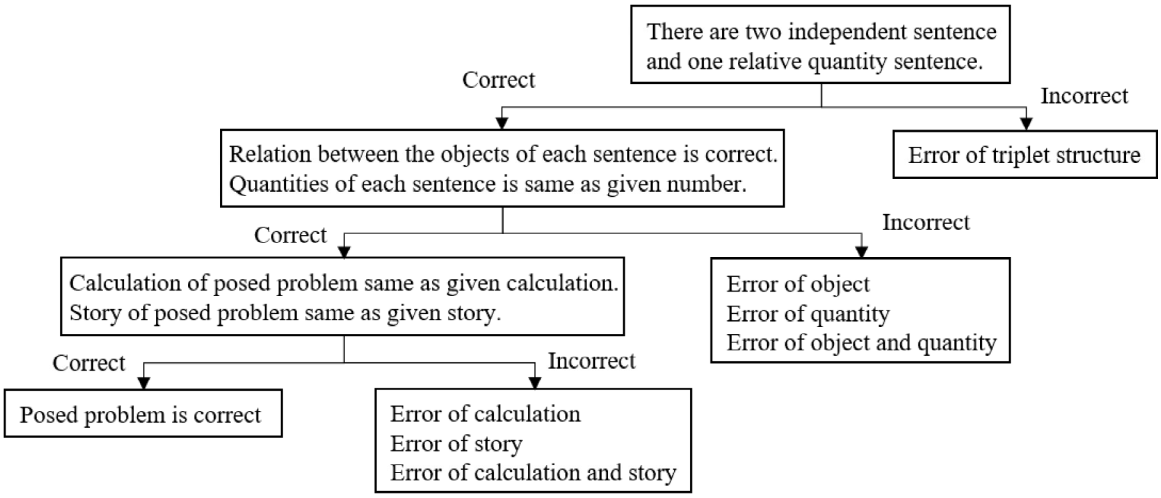

Figure 4. Diagnosis of Posed Problem by MONSAKUN Touch (Yamamoto et al, 2016).

The errors of posed problem are shown in Figure 4. First, MONSAKUN Touch diagnoses that pose problem composes of two independent quantity sentences and one relative quantity sentence. If the posed problem doesn't satisfy this restriction, the posed problem has the error called the error of triplet structure. Second, the correspondence relation between each quantity of posed problem and given quantities in assignment and the correspondence relation between each object in posed problem are diagnosed. These errors call the error of quantity and the error of object. Third, the calculation and story of posed problem correspond to the assignment is diagnosed. If the calculation of posed problem doesn't correspond to given one, the problem has the error of calculation. If the story of posed problem is not corresponded to given one, the problem has the error of story. We analyzed these errors in the experimental use.

4. Experimental Use

4.1 Method

The subjects were sixteen students in special classroom at junior high school in Hiroshima. These subjects joined from three special classrooms. They have already finished learning the arithmetic word problems. They were divided into three groups. First, nine subjects has our targeted reading disability (targeted subjects). Second, six subjects doesn't have reading disability (non-targeted subjects). Third, one subject has massive reading disability. All subjects are mild or medium intellectual disability. Intellectual disability is known as general learning disability and mental retardation but it is defined by an IQ score under 70. Because third group subject cannot read a word, the teacher read for her a given sentence cards, assignment and feedback on MONSAKUN Touch. In this experimental use, we were examined these assumption: (a) If the subjects can read the simple quantity sentence, they can exercise by the problem-posing as sentence integration, (b) subjects improve their ability for problem-posing, (c) subjects improve their problem solving and understanding of problem structure performances, (d) MONSAKUN Touch is useful for teacher to realize the lesson by problem-posing.

This experimental use has been performed during seven lessons. (Step.1) Subjects work on a pretest that consists of usual problem-solving test, extraneous problem-solving test (Muth, 1992) and problem-posing test in one lesson (forty-five minutes per one lesson). The full mark of usual problem-solving test is sixteen. The full mark of extraneous problem-solving test is sixteen. Usual problem-solving test is same as problem-solving test in arithmetic textbook. The extraneous problem-solving test includes extraneous information that is not necessary to solve the word problem. It is more difficult for learner to solve the extraneous problem than to solve the usual problem. In problem-posing test, the subjects are required to pose problems that can be solved by one-step addition or subtraction in time. (Step.2) The subjects work on a pre-problem-posing by using MONSAKUN Touch in one lesson. In this exercise, teacher didn't support subjects for posing problem. (Step.3) Lectures of arithmetic word problem by using MONSAKUN Touch are performed in three lessons. First lesson is composed of teacher's lecture about triplet structure and exercising by MONSAKUN Touch (level one) with teacher's support. One teacher taught in this lesson. Other lessons are only exercising by MONSAKUN Touch with teacher's support. In this time, the teacher uses a monitoring system for observing the learners learning data. Second lesson deals with level two and three. Third lesson deals with level four and five. Four teachers taught in these lessons. If subject finish to exercise the targeted level, they are repeat to exercise the targeted level and previous level. (Step.4) Post-problem-posing by using MONSAKUN Touch is performed in one lesson. (Step.5) The subjects work on a posttest. The teachers answered a questionnaire and an interview after all lessons finished. Four teachers who joined its experimental use answered its interview. The problems of posttest are same as pretest but its order is changed.

4.2 Results

4.2.1 Analysis of Log Data in Pre and Post Problem-posing

Average number of posed problem per minutes is 3.1 problems in all subjects. Average number of posed problem by targeted subjects is 3.96 problems. In regular classroom at elementary school, students posed 2.8 problems per minutes (Yamamoto et al, 2012). Thus, the subjects in special classroom are posed problem same as the subjects in regular class by MONSAKUN Touch.

Next, we categorized this analysis based on kind of posed problem and given calculation. If the subject cannot finish the all assignment in each level, its data is excluded. Here, a log data of non-targeted subjects is analyzed. This log data is shown in Table 2. In the analysis of level one, there was no significant difference in each error between pre-problem-posing and post-problem-posing because these learners don't have reading disability and there is few number of their error in pre-problem-posing. In the analysis of level two and three, there was only a significant difference in the error of triplet structure between pre-problem-posing and post-problem-posing (Paired t-test, p=.03), and effect size is large ($|d|$=1.72). There was no significant difference in each error of level four and five between pre-problem-posing and post-problem-posing but the assignments of level four and five are very difficult for a learner in regular class as well as these subjects.

The analysis of log data of targeted subjects is described. This log data is presented in Table 3. In the analysis of level one, there was a significant difference in the error of triplet structure between pre-problem-posing and post-problem-posing (Paired t-test, p=.04), and effect size is large ($|d|$=1.7). Also, there was a significant difference in the error of quantity and object between pre-problem-posing and post-problem-posing (Paired t-test, p=.02), and effect size is large ($|d|$=1.5). In the analysis of level two and three, there was a significant difference in the error of triplet structure between pre-problem-posing and post-problem-posing (Paired t-test, p=.002), and effect size is large ($|d|$=2.3). There was no significant difference in each error of level four and five between pre-problem-posing and post-problem-posing. The reason of this result is same as the case of non-targeted subjects.

Table 2: Number of Each Error in Non-targeted Subjects.

		Pre-problem-posing		Post-problem-posing		
Level	Type of error	M	SD	M	SD	
1 (N=5)	Story, Calculation	1.4	1.95	0.4	0.89	n.s.
	Object, Quantity	0.8	0.84	0	0	n.s.
	Triplet structure	8.6	12.03	2.6	5.27	n.s.
2, 3 (N=5)	Story, Calculation	6	4.06	1.6	2.07	n.s.
	Object, Quantity	15	13.61	1.8	1.92	n.s.
	Triplet structure	20.2	12.81	3.6	4.83	*
4, 5 (N=5)	Story, Calculation	14.2	10.92	14.8	6.38	n.s.
	Object, Quantity	11.8	7.56	10.2	8.17	n.s.
	Triplet structure	48.4	65.36	71.2	59.83	n.s.

** p<.01, * p<.05

Table 3: Number of Each Error in Targeted Subjects.

		Pre-problem-posing		Post-problem-posing		
Level	Type of error	M	SD	M	SD	
1 (N=7)	Story, Calculation	4.14	3.48	1.86	2.34	n.s.
	Object, Quantity	16.71	12.89	2.57	2.23	*
	Triplet structure	59.14	30.43	17.86	14.62	*
2, 3 (N=4)	Story, Calculation	6.50	4.51	6.00	3.92	n.s.
	Object, Quantity	18.75	5.56	7.50	4.04	**
	Triplet structure	44.25	17.39	35.00	20.52	n.s.
4, 5 (N=4)	Story, Calculation	27.50	43.94	13.75	8.96	n.s.
	Object, Quantity	13.25	10.87	12.50	4.43	n.s.
	Triplet structure	83.75	125.77	83.75	68.96	n.s.

** $p<.01$, * $p<.05$

Table 4: Number of Subjects who finished Each Level.

		Lv.1	Lv.2	Lv.3	Lv.4	Lv.5
Non-targeted Subjects (N=5)	Pre-problem-posing	5	5	5	1	0
	Post-problem-posing	5	5	5	2	1
Targeted Subjects (N=7)	Pre-problem-posing	7	4	4	0	0
	Post-problem-posing	7	7	7	2	2

In addition to these results, one subject with massive reading disability has caused the one error of triplet structure in post-problem-posing exercise, first. However, she didn't cause the error of triplet structure from twice to fourteen times diagnosis. This result suggested that the problem-posing as sentence integration is effective method for massive reading disability student. Table 4 shows the number of subjects who finished each level. From the results of Table 4, all subjects learned the method of posing problem because their reached levels are improved.

The results of log data pointed out that the student with reading disability can exercise by problem-posing if they use MONSAKUN Touch. Also, this results of log data shows that MONSAKUN Touch improves all subject's problem-posing ability without the level four and five that required them to pose the reverse thinking problem based on given calculation numerical relation. From mentioned above, we demonstrate the assumption (a). However, they couldn't improve their ability of problem-posing in level four and five. For improving these results, we need to sophisticate the level of assignment more gradually.

4.2.2 Analysis of Pretest and Posttest

A score of each pretest and posttest is presented in Table 5. One student absent from the posttest in usual problem-solving test. Additionally, one student couldn't work on extraneous problem-solving test because of time. There is no significant difference between pretest and posttest in usual problem-solving test. About this reason, we thought that it is difficult for several subjects to concentrate to solve problems. Actually, a score of two subjects in pretest and posttest are zero. There is also no significant difference between pretest and posttest in extraneous problem-solving test. We thought that the reason of this result is same as usual problem-solving test. A score of five subjects in pretest and posttest are zero. So, it is difficult for them to solve the general problem solving test.

Only eight subjects described problems in problem-posing test. There is no significant difference between the number of posed correct problem in pretest and posttest but this number is increased from 2.5 to 4. Moreover, one subjects posed one reverse thinking problem in posttest. The results of problem-posing test and log data are suggested the assumption (b) but we didn't confirm that assumption (c). The tests for examining the performance of problem-solving and understanding of problem structure have to be improved.

Table 5: Score of Each Pretest and Posttest.

	Pretest		Posttest		
	M	SD	M	SD	
Usual Problem-solving test (N=15, Max score=16)	7.60	4.67	7.40	5.36	n.s.
Extraneous Problem-solving test (N=14, Max score=16)	3.64	5.37	4.29	5.30	n.s.
Problem-posing test (N=8)	2.50	2.07	3.50	2.67	n.s.

4.2.3 Analysis of Questionnaire and Interview

The result of questionnaire for teacher is shown in Table 6. From the question (1), they find it is very hard for them to teach problem-posing without MONSAKUN Touch in special classroom. They also said that teachers need to have enough experience in order to teach problem-posing. And it is difficult to design a lecture of problem-posing because teachers let students pose few problems in one lesson generally. However, if they apply MONSAKUN Touch to their lecture, the students with reading disability can pose many problems. Here, one teacher answered "neutral" in question (1) because she has never taught problem-posing. Therefore, these teachers consider that MONSAKUN Touch is useful software to teach the arithmetic word problem that can be solved by one-step addition or subtraction by problem-posing in special classroom if a learner with reading disability can read and understand the simple quantity sentence. So, three teachers answered question (2) "neutral" but they would like to use MONSAKUN Touch continually.

In the results of interview, these teachers suspected that subjects are able to pose problem by using MONSAKUN Touch but most subjects have difficulty in exercising by problem-posing and they cannot concentrate on a problem-posing for a long time. These teachers also suspected that some subjects can learn the arithmetic word problem by using MONSAKUN Touch before experimental use but many subjects cannot learn because of their disability. However, all subjects concentrated on a problem-posing during lesson and the number of error was decreased. Besides, most subjects answered that the problem-posing as sentence integration is difficult exercise but they enjoy learning by problem-posing and want to learn again. These results are better than the results that the teachers suspected. These results also demonstrate the assumption (d).

Table 6: Result of Questionnaire for Teacher (N=4).

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
(1) Is it easy to teach problem-posing without MONSAKUN Touch?	0	0	1	0	3
(2) Is it effective to use problem-posing as sentence integration for reading disability leaner?	0	0	3	0	1
(3) Is it easy for you to use MONSAKUN Touch in your class?	1	2	1	0	0
(4) Would you like to use MONSAKUN Touch in your class continually?	3	1	0	0	0

5. Conclusions

We designed and developed the learning environment for problem-posing as sentence integration. On this learning environment, learners pose the arithmetic word problem as selecting and arranging given simple sentence cards. In usual problem-posing, learners need to write an arithmetic word problem with some sentences. So, learners with reading disability cannot exercise problem-posing because they feel difficulty in writing a sentence and reading long sentence. Therefore, it is virtually impossible for them to learn by problem-posing. However, we assumed that these learners exercise the problem-posing by using our learning environment if they can read the simple sentence. Through the experimental use of the system, it was confirmed that the learners could pose the problem. Moreover, the teachers accepted that our learning environment is effective for targeted learner. These results are better than the results that the teachers suspected. It is believed that the leaner with reading disability who can read the simple sentence could learn by problem-posing for our learning environment. However, it is not sufficient to confirm the learning effect like problem-solving performance and several functions of our system have to be improved.

As our future works, we have to sophisticate the level of assignment and analyze the results of this experimental use in more detail. Furthermore, we are going to perform the experimental use continually for confirming the effect of our learning environment.

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