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A Case Study of Interactive Learning Environment for Building Structure of Arithmetic Word Problem in Language Delay

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Abstract: In special classroom, students are taught solution methods of arithmetic word problems carefully, and the teacher doesn't teach highly effective learning like problem-posing because it is said that its learning load is high for students in special classroom. On the other hands, we tried to decline the cognitive load of problem-posing by analyzing the cognitive load of problem-posing and student's disability. And then, we developed learning environment based on this analysis. As a result, students with language delay can learn by problem-posing. Therefore, we assumed that it could realize a learning by building structure which is considered to be more advanced and difficult. In this paper, developed learning environment that can build the structure of arithmetic word problem and its experimental use are reported. As a result, students can exercise by building structure and improve their problem-posing performances.

Keywords: language delay, problem-posing, arithmetic word problem, information structure

1. Introduction

Students belonging to special classroom have some disabilities. For examples, disabilities are learning disabilities (e.g. dyslexia), communication disorders, emotional and behavioral disorders (e.g. ADHD) and so on. Therefore, students of special classroom learn an arithmetic word problem by exercises conducted in general classes such as problem solving through their disabilities (William, 2007). Moreover, generally, a student in special classroom is supported to spend their everyday life without problem (Fernández-López et al., 2013). So, their learning progress is slow.

Of course, the teacher would like to do the same teaching as the general classroom if they can do, and they would like to do if they can provide high quality learning. However, because higher loads are generated for more advanced learning (e.g. problem-posing), the teacher judges that it is difficult for students in special classroom who are difficult to learn by problem solving.

We model an arithmetic word problems and develop a learning environment by constructing arithmetic word problems (Hirashima et al., 2007; Yamamoto et al., 2012). For example, it is a learning environment for problem-posing and building structure learning. These are highly difficult learnings that special classroom's students cannot learn. However, we analyzed various cognitive loads of learning and disabilities of learners in special classroom. And by declining the load related with the disabilities by a system, they were able to learn by problem-posing using our system (Yamamoto and Hirashima, 2016; Yamamoto et al., 2016).

In this study, we analyzed the various cognitive loads and targeted disability, and we assumed that it could realize more advanced building structure learning than the problem-posing, so we carried out experimental use in the special classroom and analysis of the result.

2. Targeted Language Delay and Our Method

The object of this research is a student who is difficult to understand language (e.g. Language Delay). Generally, when understanding sentences, we first divide the target sentences into meaningful chunks.

Then, after dividing the sentences into minimum units such as words, compare it with the mental dictionary, we understand the meaning of the whole sentence (Coltheart et al., 2001; Perry et al., 2007). Therefore, it becomes difficult to divide sentence into meaningful chunks as long sentences, making it difficult to understand sentences.

This difficulty is remarkable for students who make difficulty understanding sentences. For example, several students cannot understand if two or more sentences such as "there are three apples" are unified, and some students cannot understand this sentence as mentioned above. Because they are difficult to understand such sentences, they have to learn an arithmetic word problems by solving problem by shortening sentences or giving pictures by teachers. Other researcher suggested that the learning environment to help these learner by using dynamic visual tool when solving mathematics problems (Peltenburg et al., 2009). And such language delay also interferes with everyday life, so it was necessary to learn about daily life as well. Therefore, their learning progress is very slow.

Cognitive load theory which clarifies the load at the time of learning are proposed (Sweller et al., 1998). In cognitive load theory, the three cognitive loads are defined: extraneous load, intrinsic load and germane load. Here, we consider only extraneous load. Extraneous load is not concerned by learning and decline the amount of resources available to process the intrinsic and germane load. Therefore, it is said that it is a load to be declined. Problem solving and problem-posing in arithmetic word problem are “word problems”, so learners must read or write sentences by themselves. However, reading comprehension and sentence description are loads unrelated to learning an arithmetic word problems. In particular, the description of sentences is far more difficult than reading comprehension. Therefore, due to the load not related to learning, the learner cannot learn by problem-posing.

Our problem-posing are required learner to pose problem by selecting and arranging given simple sentence cards (Yamamoto et al., 2012). Our target arithmetic word problem can be solved with one-step addition or subtraction. This is going to be described in the next chapter. By using this type of problem-posing, we assumed that learners can learn arithmetic word problem through problem-posing by selecting and arranging simple sentences if learners can read even simple sentences given by our learning environment. And previous research showed that this learning environment realized learning by problem-posing and learning effect (Yamamoto and Hirashima, 2016; Yamamoto et al., 2016).

3. Learning by Building Structure and Reading Disability

3.1 *Structure of Arithmetic Word Problem*

In this research, we targeted an arithmetic word problem which can be solved by one-step addition or subtraction. This structure is explained with reference to Figure 1. This arithmetic word problem consists of three simple sentence expresses quantitative concept. These sentence cards contain quantity, object and attribute. For example, in first sentence, the quantity is five, the object is apple, attribute is “there are”. Attribute shows the kinds of quantity that are independent quantity expresses existence of quantity, and relative quantity expresses relation between other existence quantities. For example, the third sentence contains the attribute that is “altogether”. This attribute expresses the relation between apple and orange. The story of arithmetic word problem is decided by relative quantity sentence, where are combine, change-increase, change-decrease and compare. We call this model as triplet structure model (Hirashima et al., 2014). Also, the difference between story and problem is the given three simple sentence cards include required value or not. In our problem-posing, learner gives a calculation and the story and then he/she is required to pose the problem by selecting and arranging a given sentence cards.

The relation of these quantities is shown in Figure 2. We call this expression part-whole relation and the block sets the simple sentence cards called Tape-Block. Above part of Tape-Block expresses the whole quantity, for example, the sentence of apple and orange. Below parts of Tape-Block expresses the part quantity, for examples, the sentence of apple and the sentence of orange. The relation between three quantities in arithmetic word problem are visualized by this model in each kind of story. Therefore, this kind of arithmetic word problem include three numerical relation, where are one addition and two subtraction. In Figure 2, there are three numerical relation that are “8-5=?”, “8-?=5” and “5+?=8”. We called this relation the one addition and two subtraction relation. This relation is different in each story.

There are two kind of numerical relation in the arithmetic word problem that can be solved by one-step addition or subtraction. The story of this arithmetic word problem is divided into addition story and subtraction story. Addition story is usually expressed by combine story or change-increase story. Subtraction story is usually expressed by change-decrease story or comparison story. So, the story of Figure 1 is addition story. Therefore, the numerical relation of this problem expresses as “5+?=8” because the story of Figure 1 is addition story. We call this numerical relation the story numerical relation. On the other hands, we are able to solve this problem by “8-5”. We call this numerical relation the calculation numerical relation. In this problem, story numerical relation and calculation numerical relation are different. We call this kind of problem "reverse thinking problem". Reverse thinking problem is much harder than "forward thinking problem" where story numerical relation and calculation numerical relation are the same ones.

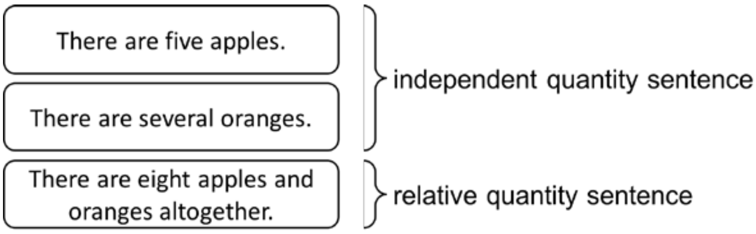


Figure 1. Example of Problem by Triplet Structure Model.

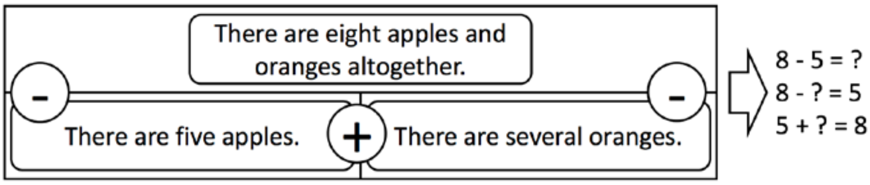


Figure 2. Part-Whole Relation on Tape-Block and Three Numerical Relation of Figure 1’s Problem.

3.2 Relation Between Structure of Arithmetic Word Problem and Reading Delay

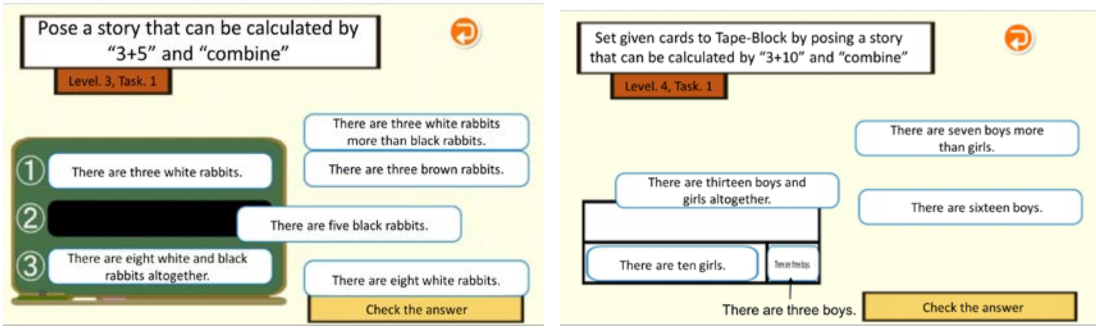
In previous research, it was found that students who is difficulty understanding language can realize learning with a high-level difficulty by declining the load that related by language understanding and included in extraneous load. In other words, if their disability is same as loads included in extraneous load, advanced learning can be realized. Therefore, in this research, we assumed that we could develop a learning environment that realizes the exercise of building above structure more difficult and effective than problem-posing.

If learner would like to think about problem structure, the visualization and building structure are effective (Hirashima and Hayashi, 2016). Therefore, it is the purpose of building structure learning to operate and understand the triplet structure model and the one addition and two subtraction relation of Figure 2 described in the previous section. The activity is done by the learner is mainly the problem-posing as sentence integration and the simple sentence setting to Tape-Block. By analyzing the cognitive load of this exercise, the cognitive load of problem-posing is the same as that of the previous research. It is necessary for the cognitive load of building structure to read and understand the simple sentence cards, and understand Tape-Block expression. Reading and understanding of the simple sentence card are a load that is required even in problem-posing as sentence integration, so a target learner can read a simple sentence. In addition, since Tape-Block is a graphical expression and does not involve sentence comprehension, we thought that the target learner can understand this expression. So, we performed experimental use of its learning environment that realizes the building structure exercise.

4. Interactive Learning Environment for Building Structure: MONSAKUN Tape-Block

Figure 3 is interface of learning environment for building the arithmetic word problem structure called MONSAKUN Tape-Block. First, learner log in this system by selecting their class and grade. Next, the learning environment display the interface of level selection and then, learner selects one of levels one to ten in this interface. The assignments of this learning environment are omitted for the page limited but it is designed to gradually learn the structure. When learner selects any level, our learning environment shows the interface shown in Figure 3.

Interface for problem-posing shown in Figure 3 (a) gives learner the assignment and several sentence cards. Learner can pose the problem by selecting three sentence cards from given ones and arranging them in proper order. If the posed problem is satisfied given calculation and story, MONSAKUN Tape-Block feeds back the correct and shows next assignment. Through this exercise, learner can learn the triplet structure model. On the other hands, interface for building part-whole relation is shown in Figure 3 (b). This interface is required learner to build a part-whole relation by setting given sentence cards to Tape-Block to satisfy given calculation and story. By this learning, learner understands about the part-whole relation. These interface feedbacks two feedbacks. One feedback is flag feedback that replies only correct or not. Other one is pointing hint that points learner's attention to errors.



(a) Problem-posing (b) Building Part-Whole Relation

Figure 3. Interface of MONSAKUN Tape-Block for problem-posing.

5. Experimental Use

5.1 Subjects and Procedure

The subjects were thirteen students at special classroom in junior high school. They have already finished to learn the arithmetic word problems that can be solved by one-addition or subtraction. There are a few subjects because students at special classroom in Japan are small. We divided them into following three groups. Four subjects don't understand the simple sentence but they can read simple sentence (group A). Four subjects understand and read the simple sentence but they cannot read long sentence that is combined more than two simple sentence (group B). Five subjects understand long sentence (group C).

We use two our learning environments that are learn by problem-posing and building problem structure. There are called MONSAKUN Touch 1 (MT1) and MONSAKUN Tape-Block (MTB). If learner not enough to understand the problem structure, he/she cannot pose the problem by MT1. So, we use the MT1 for verifying the understanding of problem structure in each subject. In this experimental use, first, a subject exercise by MT1 as pre-test in one lessons. One lesson is forty-five minutes. Second, a subject learns by MTB in three lessons. Subjects are taught the method of each exercise at twenty minutes in first lesson. They exercise by MTB at remaining twenty-five minutes. Finally, they exercise the problem-posing by MT1 in one lesson.

Four teacher in special classroom and one teacher teach mathematics are join in experimental use. They evaluated the subjects are not able to exercise and learn by MTB before we perform experimental use because learning problem structure is very high-level learning for students in special classroom. However, teachers would like to realize the learning problem structure of the student can. So, we suggested the learning method by visualizing and building the structure of arithmetic word problem. We also assumed that (a) Subjects who can understand the simple sentence are able to exercise the learning by problem structure, (b) Subjects who can understand the simple sentence are able to improve their problem-posing performance.

5.2 Results

We repot the results of experimental use that are a result of MTB, MT1. We couldn't perform the statistical analysis because the number of subjects are small. First, we describe about the result of MTB by Table 1. All subjects concentrated to exercise during each lesson. Group A achieved level 7. Group B and C achieved level 10. Average of accuracy rate is sixteen percent in group A. Average of accuracy rate of group B is forty-five percent, group C is seventy-one percent. Therefore, all subjects can exercise the learning of problem structure by MTB but group A is difficult to learn.

The result of MT1 is shown in Table 2. This table shows the average correct number of problem-posing in MT1 in each kind of problem. The assignment of reverse thinking problem-posing is most difficult in problem-posing exercise and the forward thinking (forward calculation) is most easy. All subjects can pose the problem by MT1 and they improve their performance of problem-posing in reverse thinking problem and total. There is an approached significant between the average number of correct problem in pretest and posttest (Paired t-test, $p=.07<.1$). There is a significant difference between the average number of correct reverse thinking problem in pretest and posttest (Paired t-test, $p=.02<.05$). Next, we analyzed the data of reverse thinking problem in each group. The correct number of group A didn't increase because they didn't learn by MTB enough. The correct number of group B increased a lot. This result suggested that the learner of group B has be able to exercise and learn the problem structure by using MTB. In group C, the correct number increased so this group also has been able to exercise and learn the problem structure by MTB.

Table 1: Average Accuracy Rate of MONSAKUN Tape-Block in Each Level (MAX: 1).

Group	Lv1	Lv2	Lv3	Lv4	Lv5	Lv6	Lv7	Lv8	Lv9	Lv10
A	0.42	0.28	0.23	0.08	0.11	0.29	0.16	0	0	0
B	0.54	0.40	0.48	0.36	0.52	0.67	0.71	0.36	0.3	0.14
C	0.84	0.78	0.86	0.31	0.78	0.74	0.53	0.81	0.74	0.67

Table 2: Average Correct Number of Problem-posing in MONSAKUN Touch 1.

	Forward thinking (Forward calculation)		Forward thinking (Reverse calculation)		Reverse thinking		Total	
MAX	12		20		20		52	
group	pre	post	pre	post	pre	post	pre	post
A	11.2	9.8	8	9.8	2	2.4	21.2	22
B	12	12	19	20	3.75	10.25	34.75	42.25
C	11.75	12	20	20	14.5	16.5	46.25	48.5
ALL	11.62	11.15	15.08	16.08	6.38	9.15	33.07	36.38

5.3 Discussion

We reported the results of experimental use in previous section. The result of exercise by MONSAKUN Tape-Block suggested that the learner with reading disability has be able to exercise by building the problem by MONSAKUN Tape-Block. Moreover, the result of pretest and posttest shows the improvement of problem-posing performance in group B and C. So, reading disability can learn the problem structure if they can understand the simple sentence. Learning problem structure is impossible learning in reading disability so this result suggested the realization of more advanced learning.

The subject of group A can exercise the MONSAKUN Tape-Block and MONSAKUN Touch 1 but they couldn't learn the problem structure. This means that it is effective for them to exercise by visualizing and building the problem structure but kit is not proper. We have to realize the learning environment for building the simple sentence. By this experimental use, we have verified the stage of reading disability. If the learner understands the arithmetic word problem that can be solved by one-step addition or subtraction, they have to understand simple sentence. So, if the learner understands the simple sentence, they can learn the structure of arithmetic word problem even though they have language disability.

In conclusion, if the learner with reading disability is given the proper kit like simple sentence for learning, they can exercise and learn more effective and difficult learning like the structure building. Of course, learning environment is needs to be interactive.

6. Conclusions

In the special classroom, careful learning is carried out due to the student's disabilities. By considering the cognitive load of learning, we are realizing more advanced learning in the special classroom by supporting only disabled activities in the system. In this research, we tried to realize the building structure learning of arithmetic word problems for students who are difficult to understand sentences. As a result of experimental use, it was found that building structure exercises by our learning environment can be realized for the target learner.

In future works, we improve the interface for reading disability and verified its effect. Also, the confirmation of our assumption in other domain like an arithmetic word problem that can be solved by one- multiplication and division is important.

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