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A Case Study of Learning Environment for Building Structures for Learners with Reading Disabilities Based on Cognitive Load Theory

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Abstract: We have developed an interactive environment for learning using the kit-build method (targeted at problem-posing). Furthermore, we intend to apply this system to special classrooms. The research domains in this study are arithmetic word problem and reading delay. We analyze the structure of the arithmetic word problem to help develop a learning environment that allows learners to pose the problems by building the units of the kit given to them in the exercise. Meanwhile, in special classrooms, teachers carefully teach disabled students arithmetic word problems using a general learning method such as problem-solving because of the students' disability. For example, a picture is used to explain the meanings of sentences in a word problem. By analyzing learning methods based on cognitive load theory, we argue that if extraneous load is consistent with the disability of the learner, a learning method could be realized that would be considered difficult to realize in a special classroom by giving learners an appropriate unit kit in the learning environment. In previous research, we performed an experiment using the learning environment for problem-posing in a special classroom at a junior high school. It is impossible to learn by problem-posing in special classrooms, but we achieved success in this exercise with our learning environment. In this research, we attempted to realize learning by directly building the structure of an arithmetic word problem, which is considered a more difficult learning task than problem-posing. Moreover, we report on an experiment we performed using this environment.

Keywords: Reading disability, kit-build, arithmetic word problem, problem structure, cognitive load theory

1. Introduction

We have developed an interactive environment to help students learn the structure of an arithmetic word problem by building a problem structure (Yamamoto et al., 2012; Yamamoto et al., 2014). For example, MONSAKUN Touch 1 is a learning environment in which a learner is able to pose an arithmetic word problem by selecting and arranging a given set of sentence cards (Yamamoto et al., 2012). The learner can learn arithmetic word problems using this system, and it is possible to estimate the learner's understanding of the structure of the arithmetic word problem in this way. Moreover, we developed a learning environment with which the structure of an arithmetic word problem can be learned by building its structure. We call this system MONSAKUN Tape-Block. These systems can be used by students in general classroom, and we found them effective for learning arithmetic word problems that can be solved by one-step addition or subtraction.

In this study, we targeted students with reading disabilities among those enrolled in a special support class. Reading disability is a disorder in which great cognitive load must be applied when reading a sentence, and it has serious detrimental effects on every type of learning. Students who have difficulty reading sentences cannot write sentences, and so students with reading disabilities also have difficulty writing. It is also known that there are many students with reading disabilities among students enrolled in special classrooms. Therefore, teachers teach these students arithmetic word problems much more carefully than in general classrooms. For example, teachers teach students how to solve arithmetic word problems using pictures or explaining the meaning of sentences (Bender, 2007; Xin et al., 2005). For that reason, activities for extracting quantitative relations from problem sentences are sometimes closely supported by teachers, and so it is possible to reduce learning effects in problem-solving. In addition, several researchers have developed learning environments that can help learners gain the necessary knowledge for spending daily life, which is necessary because for students with reading disabilities this task will interfere with their daily life (Fernández-López et al., 2013). Although there are lectures focusing on such learning in special classrooms, the learning progress of special classroom students are delayed and the goals of their learning will be lower than the goals of the general classroom.

Problem-posing exercises have been proposed as one of the most effective learning methods for arithmetic word problems (Silver, 1997). It is known that problem-posing is learning that can lead to a deeper understanding of arithmetic word problems than can problem-solving. Learners need to consider the problem structure of the word problem in such exercises, and thus this type of exercise is more difficult than problem-solving. Moreover, learners also need to write the word problem in such exercises. Therefore, because learners with reading disabilities cannot write the word problems and there is not enough time to support their learning, it is impossible for learners in special classrooms to learn by problem-posing. A theory that takes into account the load of learning—namely, the cognitive load theory—has been suggested for considering the cognitive load when learners are learning (Sweller et al., 1998). The aforementioned learning support was aimed at decreasing the cognitive load of learners, but the type of cognitive load was not taken into consideration in that study. Also, generally, teachers could only teach arithmetic word problems carefully using problem-solving. On the other hand, we analyzed the cognitive load of learning and the disability of learners and found that the load related to reading disabilities was not related to learning in problem-posing exercises. Therefore, if we remove the extraneous load related to the reading disability, there is a possibility that the problem-posing exercise can be performed.

We have developed a learning environment with the kit-build method by analyzing the structure of arithmetic word problems. It is possible to change the units of the kits given to learners based on the analyzed structure of arithmetic word problems when they are learning. Therefore, we realized a problem-posing exercise for learners with reading disabilities by developing a learning environment that gave appropriate kits to such learners, who then built the kits (Yamamoto & Hirashima, 2016; Yamamoto et al., 2016). As a next step, this study attempted to realize learning by building the structure of arithmetic word problems for learners with reading disabilities, because this learning is more effective for understanding arithmetic word problems than are problem-posing and problem-solving. Section 2 discusses learners with reading disabilities and the related cognitive load. Section 3 presents the structure of arithmetic word problems, learning by building its structure, and cognitive load theory. Section 4 introduces our learning environment for building structure. Section 5 reports an experimental use. Section 6 presents our conclusions.

2. Targeted Reading Disability and Cognitive Load of Reading

A special classroom is a small-group classroom that includes students who need special support for their learning. In order to address their disability, the teacher teaches behaviors, communication, and other needs of daily life as career education. These students have one or more disorders in the ability to listen, think, speak, read, write, spell, or do mathematical calculations. As mentioned earlier, this research is intended for students who face difficulties in reading sentences. They experience a greater cognitive load than do ordinary people when they read sentences, and so reading comprehension of the sentences is slow or impossible for them. Therefore, in order to let learners learn, the teacher decreases the load of reading sentences by reading sentences on their behalf, dividing sentences into short units, or using pictures expressing the meaning of sentences.

Generally, when we understand sentences, we divide them into meaningful chunks; then, after dividing the sentences into minimum units such as words and comparing them with the cognitive dictionary, we understand the meaning of the whole sentence (Coltheart et al., 2001; Perry et al., 2007). Therefore, learners with reading disabilities have difficulty understanding the meanings as the sentences become longer because it is very hard for them to divide sentences into meaningful chunks.

For example, some students with reading disability cannot understand a sentence such as “there are three apples and four oranges, so there are seven apples and oranges in total,” but if the sentence is divided as “There are three apples. There are four oranges. There are seven apples and oranges in total,” some of the students can understand the sentences. Similarly, even if they cannot understand “There are three apples,” they can understand “Apple.” Therefore, learners with reading disabilities have a different degree of load in recognizing sentences. Of course, if learners feel difficulty reading sentences, they also find it difficult to write sentences. Thus, learners with reading disabilities feel greater difficulties reading as sentences become longer, and they find it more difficult to write sentences than to read sentences.

3. Learning by Building Structure and Cognitive Load Theory

3.1. Structure of Arithmetic Word Problem

In previous research, we defined the structure of arithmetic word problems that can be solved by one-step addition or subtraction (Yamamoto et al., 2012). We show this definition of arithmetic word problems in Figure 1. This arithmetic word problem consists of three simple sentences expressing a quantitative concept. These sentence cards contain a quantity, object, and attribute. For example, in the first sentence, the quantity is five, the object is apple, and the attribute is “there are.” The attribute shows the kinds of quantities: independent quantities express the existence of a quantity and relative quantities express relations between other existence quantities. For example, the third sentence contains the attribute “altogether.” This attribute expresses the relation between apples and oranges. The story of arithmetic word problems is decided by relative quantity sentences, which have the forms combine, change-increase, change-decrease, and compare. We call this model the triplet structure model (Hirashima et al., 2014). Also, the difference between the story and the problem is whether or not the given three simple sentence cards include the required value. In our problem-posing, the learner is given a calculation and the story as the assignment, and then he/she is required to pose the problem to satisfy the given assignment by selecting and arranging the given sentence cards.

The relations of these quantities are shown in Figure 2. We call this expression the part-whole relation, and the block shows the relation among the quantity of three simple sentence cards called Tape-Block. The upper part of the Tape-Block expresses the whole quantities, for example the sentence about apples and oranges. The lower parts of the Tape-Block express the part quantity, for example, the sentence about apples and the sentence about oranges. The relations between the three quantities in the arithmetic word problem are visualized by this model in each kind of story. Therefore, this kind of arithmetic word problem includes three numerical relations, which in this case are one addition and two subtractions. In Figure 2, there are three numerical relations, “8−5=?”, “8−?=5,” and “5+?=8.” We call this relation the “one addition and two subtractions” relation.

There are two kinds of numerical relations in the arithmetic word problems that can be solved by one-step addition or subtraction. The story of this arithmetic word problem is divided into the addition story and the subtraction story. An addition story is usually expressed by a combine story or a change-increase story. A subtraction story is usually expressed by a change-decrease story or a comparison story. Therefore, the story of Figure 1 is an addition story. Therefore, the numerical relation of this problem is expressed as “5+?=8” because the story of Figure 1 is an addition story. We call this numerical relation the story numerical relation. On the other hand, we are able to solve this problem with “8−5.” We call this numerical relation the calculation numerical relation. In this problem, the story numerical relation and calculation numerical relation are different. We call this kind of problem a “reverse thinking problem.” Reverse thinking problems are much harder than “forward thinking problems,” in which the story numerical relation and calculation numerical relation are the same.

We defined the structure of an arithmetic word problem as consisting of a triplet structure model, a part-whole relation (one addition or two subtraction relations), the definition of the problem, and the story numerical relation and calculation numerical relation. Thus, the learner learns the problem structure by selecting and arranging simple sentence cards for the relations among these models. Therefore, the learner comes to understand the simple sentence, the Tape-Block, and the numerical relation if they practice exercises using our learning method.

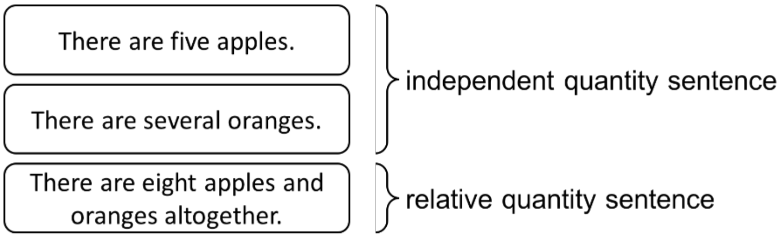


Figure 1. Triplet Structure Model.

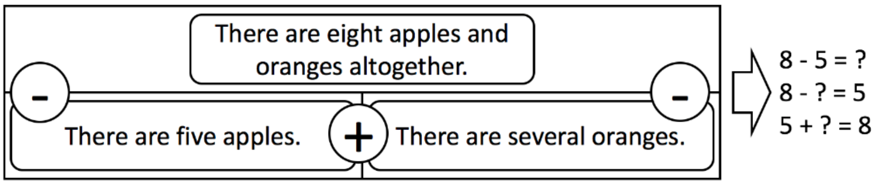


Figure 2. Part-Whole Relation in the Tape-Block and Three Numerical Relations of the Problem in Figure 1.

3.2. Learning by Building Structure

In order to understand the structure of arithmetic word problems, learners must understand the triplet structure model, part-whole relation, difference between the problem and story, and two quantity relations (the story numerical relation and calculation numerical relation). In this research, we suggest exercises to build the problem structure for understanding these elements. The reason we let learners build the problem structure is that almost all students who learn by problem-posing understand the arithmetic word problem by a keyword (Hegarty et al., 1995). For example, they think that “combine” means addition. We assumed that special classroom students are the same. Also, if learners would like to think about the problem structure, the visualization and building structure are effective (Hirashima & Hayashi, 2016a, 2016b).

Let us now explain the exercise for understanding each element. If the learner learns the triplet structure model, he/she should build this model. This exercise is the same as the problem-posing in previous research (Yamamoto & Hirashima, 2016). In this exercise, the learner is given an assignment and several simple sentence cards like “There are three apples.” The assignment requires posing a problem that satisfies the given story and calculation. At this time, the learner poses a problem by selecting three simple sentence cards from the given sentence cards and arranging them in the proper order. The given sentence cards include three correct cards and two or three dummy cards that would cause an error.

Next, the exercise for understanding the part-whole relation is described. If the learner learns the part-whole relation of the problem, he/she should build it as well as problem-posing. In this exercise, the learner is given several simple sentence cards (or a problem expressed by simple sentence cards), a part-whole relation not applied in any simple sentence cards (excluding the simple sentence card from Figure 2), and an assignment. There are two main types of exercises in this learning. One is to infer the problem from several given simple sentences and build the part-whole relation of the problem. The other is to build the part-whole relation of the problem using the three given sentence cards that express the problem. In either exercise, the learner is required to apply three simple sentence cards to the part-whole relation in the blank. In the latter exercise, the learner learns the correspondence between the part-whole relation and the triplet structure model.

Finally, the way to learn the definition of the problem is just to perform the task of changing one quantity in the given or posed problem to an unknown. Also, regarding the two quantity relations (the story numerical relation and the calculation numerical relation), the learner can learn by deriving each quantity relation from the part-whole relation. Through these exercises, the learner can learn the numerical relation in an arithmetic word problem, the part-whole relation, the triplet structure model and the relation between these models.

3.3. Cognitive Load Theory and Each Exercises

Table 1 shows the cognitive load of each method for learning arithmetic word problems based on cognitive load theory (Sweller et al., 1998). The target learning methods are the usual problem-solving, the usual problem-posing, problem-posing as sentence integration (our suggested problem-posing), and learning by building structure. Intrinsic load is the fundamental cognitive load required for the exercise. Extraneous load is a cognitive load that is not necessary for learning but occurs during the exercise. Therefore, it is said that the extraneous load has to be reduced first. Germane load refers to the cognitive resources used in learning. Therefore, in any learning shown in Table 1, the germane load is the load of generating a schema for the structure of an arithmetic word problem.

We now consider the cognitive load of learners with reading disabilities discussed in Section 2. Learners with reading disabilities feel difficulty in learning activities with cognitive loads related to reading and writing sentences because these cognitive loads are very high for them. In usual problem-solving, the extraneous load includes that of reading comprehension of the sentences as the problem is read. Therefore, when the learner performs an exercise in usual problem-solving, the teacher reads the sentences instead or converts the story of the word problem into a picture so as to decrease these cognitive loads. Next, in usual problem-posing, the load of writing sentences is included in the extraneous load as “Write problem.” It is very difficult or impossible for learners with reading disabilities to write sentences, and so they cannot learn by problem-posing. However, in these exercises, the cognitive loads for reading and writing sentences are extraneous loads unrelated to the learning task. Therefore, we assumed that learners with reading disabilities can perform various exercises if we can eliminate this load through the learning environment. In other words, we realized the type of learning that learners with several disabilities can learn by themselves through trial and error without the teacher’s support. For example, in problem-posing as sentence integration, the learner poses the problems by building several simple sentence cards, not by writing word problems.

In problem-posing as sentence integration, the task of writing sentences is replaced by reading simple sentences by keeping learning effect (Yamamoto et al., 2012). This method was realized by defining the model described in Section 2. In fact, problem-posing exercises that have been deemed impossible for learners with reading disabilities in previous research can be performed by them (Yamamoto & Hirashima, 2016; Yamamoto et al., 2016). Therefore, we assumed that learners with reading disabilities can solve arithmetic word problems by building the problem structure if we can extract the elements necessary for considering the problem structure and give them the problem in understandable kits. In addition, it is necessary to understand the expression of the part-whole relation (the Tape-Block). Since this is a graphical expression, we thought that it is understandable to learners with reading disabilities.

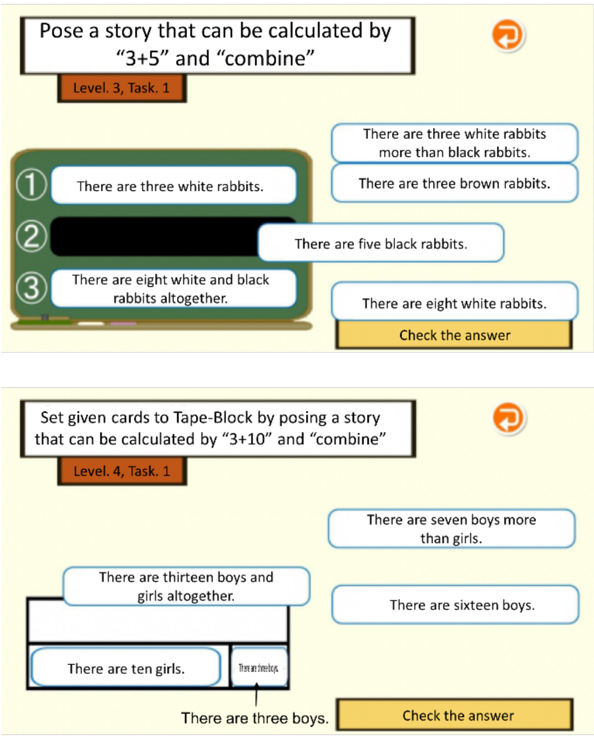
Table 1: Cognitive Load of Each Exercise.

	Usual problem-solving	Usual problem-posing	Problem-posing as sentence integration	Learning by building structure
Extraneous Load	Read problem / Write calculation	Write problem	Read simple sentence	Read simple sentence / know Tape-Block
Intrinsic Load	Finding numerical relation / Thinking each quantity	Thinking numerical relation / Thinking triplet structure model	Thinking numerical relation / Thinking triplet structure model	Thinking numerical relation / Thinking triplet structure model / Thinking one addition or two subtractions
Germane	Think solution	Think problem	Think problem	Think problem

Load	method	structure	structure	structure deeply

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

The interface and each assignment of our learning environment is described in this section. Figure 3 shows the interface of MONSAKUN Tape-Block, the learning environment for building the arithmetic word problem structure. First, the learner log in this system is used to select the learner's class and grade. After that, the learning environment displays the interface for the level selection to the user. The learner selects one of the levels from one to ten in this interface. When the learner selects any level, our learning environment shows the interface of the exercise as shown in Figure 3.



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

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

5. Experimental Use

5.1. *Subjects*

The subjects were thirteen students in a special classroom in junior high school. They had already finished learning the arithmetic word problems that can be solved by one-addition or subtraction. There were only a few subjects because there are few students in special classrooms in Japan. We divided them into the following three groups. Four subjects did not understand simple sentences but could read simple sentences (Group A). Four subjects understood and read simple sentences but could not read long sentences made up of more than two simple sentences (Group B). Five subjects understood long sentences (Group C). These groupings were based on the results of experimental use and the judgment of their teachers.

5.2. Procedure

We used two of our learning environments based on learning by problem-posing and building problem structure, called MONSAKUN Touch 1 and MONSAKUN Tape-Block. If the learner is unable to understand the problem structure, he/she cannot pose the problem in MONSAKUN Touch 1, so we used MONSAKUN Touch 1 to verify the understanding of the problem structure by each subject. In this experiment, a subject first practiced using MONSAKUN Touch 1 as a pretest for one lesson; each lesson lasted forty-five minutes. Second, the subject learned using MONSAKUN Tape-Block in three lessons. Subjects were taught the method of each exercise for the first twenty

Table 2: Assignment of MONSAKUN Tape-Block.

Level	Assignment	Learning
1	1. Select the kind of story for a given story without values. 2. Set three cards of the given story in the Tape-Block.	Relation between the story and the part-whole relation without values.
2	1. Pose a story by using three simple sentence cards without values based on the given story. 2. Set three sentence cards of the posed story in the Tape-Block.	The structure of each story and the relation between the story and the part-whole relation without values.
3	1. Pose a story based on a given story and numerical relation by using six simple sentence cards. 2. Set three sentence cards of posed story in the Tape-Block.	The structure of each story and the relation between the story and the part-whole relation.
4	1. Select and arrange three simple sentence cards in the Tape-Block using the six given simple sentence cards based on the given story and calculation. 2. Select three numerical relations expressed by the Tape-Block to form five numerical relations.	The structure of each story and the relation between the story, part-whole relation, and numerical relation on the basis of the story.
5	1. Pose a story by selecting and arranging three sentence cards from the given simple sentence cards based on the given story and calculation. 2. Select three numerical relations that are expressed by the posed story to form five numerical relations.	The structure of each story and the relation between the story and the numerical relation on the basis of the story.
6	1. Set three given value cards in the Tape-Block based on calculation. 2. Pose a story by selecting and arranging three simple sentence cards from the six given simple sentence cards based on Tape-Block in Step 1.	The relation between the numerical relation, part-whole relation, and story based on the values.
7	1. Pose the problem by selecting values from the given story. 2. Set three simple sentence cards of the posed problem in Step 1 in the Tape-Block.	The structure of the problem and the relation between the structure of the problem, part-whole relation, story numerical relation, and calculation numerical

	3. Select a story numerical relation from three given numerical relations. 4. Select a calculation numerical relation from three given numerical relations.	relation.
8	1–4. Same as Level 7. 5. Select an operator from the Tape-Block.	Same content as in Level 7 and operator of part-whole relation.
9	1. Set two value cards and one required value card in the Tape-Block based on the given story numerical relation. 2. Pose the story by selecting and arranging three simple sentence cards from six given simple sentence cards without values based on the given story. 3. Set the three values in Step 1 in each sentence card of the posed story in Step 2.	The structure of the problem and the relation between each value in the problem, the story numerical relation, and the part-whole relation.
10	Same as Level 9 but the given numerical relation is the calculation of the numerical relation in Step 1.	The structure of the problem and the relation between each value in the problem, the calculation numerical relation, and the part-whole relation.

minutes of the lesson and practiced using MONSAKUN Tape-Block for the remaining twenty-five minutes. Finally, they practiced problem-posing with MONSAKUN Touch 1 in one lesson.

Four teachers in special classrooms and one teacher teaching mathematics participated in the experiment. These teachers have evaluated that the subjects who were not able to practice and learn using MONSAKUN Tape-Block before the experiment because learning the problem structure is very high-level learning for students in special classrooms. However, But teachers would like students to learn the problem structure. We therefore suggested the learning method by visualizing and building the structure of the arithmetic word problem. We also assumed that (a) subjects who can understand simple sentences are able to practice learning with the problem structure, and (b) subjects who can understand simple sentences are able to improve their problem-posing performance.

5.3. Results

First, we describe the classroom environment during this experiment. Because it is difficult for learners in special classrooms to concentrate on learning, it is not certain that they will be able to work on exercises like these. Also, teachers reported that learning by building structures was very difficult for learners in their class and they thought that many subjects would stop working on the exercises. In fact, at first the subjects asked their teachers how to operate the tablet PCs, but after that all subjects were able to work on the exercises without a problem. In addition, there were no subjects who skipped the exercise in any lesson, and, although several subjects seemed to be struggling, all of them worked hard on their exercises.

Next, we report the results of using MONSAKUN Tape-Block and MONSAKUN Touch 1. Statistical analyses could not be performed because the number of subjects was small. First, Table 3 describes the results for MONSAKUN Tape-Block. All subjects concentrated on the exercise during each lesson. Group A achieved Level 7, while Groups B and C achieved Level 10. The average accuracy rates were 16%, 45%, and 71%, respectively, for Groups A, B, and C. Therefore, all subjects could learn problem structures using MONSAKUN Tape-Block, but Group A found it difficult to learn.

The results of using MONSAKUN Touch 1 are shown in Table 4, which shows the average correct number of the posed problems in MONSAKUN Touch 1 for each type of problem. The assignment of reverse thinking problem-posing is the most difficult problem-posing exercise and the forward thinking (forward calculation) is the easiest. The results of statistical analyses in all subjects could pose the problems with MONSAKUN Touch 1 and were able to improve their performance in problem-posing in reverse thinking problems and overall. The difference between the scores on the pretest and posttest approached significance (Paired t-test, $p = .07 < .1$). There was a significant difference between the scores on the reverse thinking problem in the pretest and posttest (Paired t-test, $p = .02 < .05$). Next, we analyzed the data for the reverse thinking problem from each group. The scores of Group A did not increase because this group did not learn sufficiently using MONSAKUN Tape-Block. The scores for Group B, however, increased greatly, which suggests that the learners in Group B were able to practice and learn the problem structure using MONSAKUN Tape-Block. The scores increased in Group C as well, so this group was also able to practice and learn the problem structure using MONSAKUN Tape-Block.

Table 3: Average Accuracy Rate of MONSAKUN Tape-Block at 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 4: Average Correct Number of the Posed Problems 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

5.4. Discussion

We reported the results of this experiment in the previous section. First, we described the situation of practical use. In all lessons, the subjects concentrated on learning by building problem structures in our learning environment. It is very difficult for students in special classrooms to maintain concentration. Also, learning by building problem structures was very difficult for the subjects but they concentrated on their exercises in all lessons, which greatly surprised their teachers. We considered the reason for this result to be that our learning environment provided kits that were understandable to subjects and gave them the results of their exercise and feedback immediately through automatic diagnosis. Therefore, learners with reading disability were able to practice by building the problem structure using MONSAKUN Tape-Block.

Moreover, the results of the pretest and posttest showed improvements in the problem-posing performance of Groups B and C. Thus, learners with reading disabilities can learn the problem structure if they can understand simple sentences. Learning by building the problem structure is an impossible task for learners with reading disabilities, so this result suggests the possibility of more advanced learning in special classrooms. The subjects of Group A, however, were able to practice using the MONSAKUN Tape-Block and MONSAKUN Touch 1 but could not learn the problem structure. This means that practicing by visualizing and building the problem structure was effective for them but the kit was not suitable for them. We thus had to realize a learning environment for building simple sentences. For example, it was considered effective for subjects in Group A to learn by building simple sentences before learning with MONSAKUN Tape-Block. This experiment verified the stages of reading disabilities. If learners are to understand arithmetic word problems that can be solved by one-step addition or subtraction, they must understand simple sentences. Therefore, if learners understand simple sentences, they can learn the structure of arithmetic word problem even though they have reading disabilities. However, learners who do not understand simple sentences need to understand them by building the elements that constitute simple sentences.

Finally, the subjects made many mistakes in MONSAKUN Tape-Block and MONSAKUN Touch 1 because the feedback of these system presented several sentences, which is not easy for students with reading disabilities to understand. Thus, most subjects only used the critical feedback that showed whether the answer was correct or not. The feedback for each system must be improved.

Using the cognitive load theory, the results of the experiment suggest that more advanced learning can be realized in special classrooms by decreasing the cognitive load subject to the learner's disability if the learner's disability affects the extraneous load. The aforementioned learning does not mean an activity where teachers carefully support learners during exercises, but one where the learner learns by himself/herself through trial and error. In this research, if learners with reading disabilities are given a suitable kit, like simple sentences for learning, they can practice more effectively and learn difficult learning tasks like structure building. We also consider that subjects who failed to learn using MONSAKUN Tape-Block could learn if they learn simple sentences by building understandable kits.

6. Conclusions

In this research, we constructed an interactive environment for learning problem structures. It is impossible for learners with reading disabilities to learn the structure of arithmetic word problems because the learner must read or write a long sentence in usual problem-solving and problem-posing, which they find difficult. We analyzed the cognitive load of these types of learning and assumed that a learner with a reading disability can learn the structure of a problem if the extraneous load in reading and writing a sentence is reduced. We suggested problem-posing exercises and structure building exercises by selecting and arranging given simple sentence cards that many learners with reading disabilities can understand.

We developed this interactive learning environment and performed an experiment using it in special classrooms in junior high school. The results show that learners with reading disabilities can practice structure building and learn the structure of arithmetic word problems if he/she understands simple sentence cards. Learners who cannot understand simple sentences are not able to learn the problem structure, but there is a possibility of their learning the problem structure if they learn by building simple sentences from a given kit.

In future research, we will improve the interface for reading disabilities and verify its effects. We will also develop the environment for learning the structures of simple sentences and its practical use. Also, the confirmation of our assumptions in other domains, such as in arithmetic word problems that can be solved by one-multiplication and division, is important.

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