A Learning Environment Case Study: Posing One-step Multiplication and Division Word Problems to Learners with Reading Disabilities

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Abstract: It is well-known that learners with reading disabilities find it difficult to read or write long sentences and need support when learning to read or write. In previous research, we have confirmed that learners with reading disabilities can build problem structure and word problems from kits themselves if they can understand and use kits within our learning environment; this work has focused on one-step addition or subtraction word problems. They can also improve their own understanding of word problems. A kit is used to build suitable problems and structures within a defined learning subject. The present paper reports on the results of an experiment to engage learners with reading disabilities in learning to solve one-step multiplication and division word problems, using our learning environment.

Keywords: Problem-posing, learning disability, arithmetic word problem, reading disability

1. Introduction

The number of students with learning disabilities is increasing year by year. According to the National Center for Learning Disabilities, 12% of a random sampling of 1,980 adults in the United States have learning disabilities (Cortiella et al., 2014) and 8% of American children whose parents have a learning disability also have learning disabilities. In Japan, MEXT (the Ministry of Education, Culture, Sports, Science and Technology) has carried out surveys of learning disabilities among junior high school and elementary school students without three regions of Japan (52, 272 students). The results show that 4.5% of Japanese students have learning disabilities. Learning disabilities interfere with the ability to learn basic skills, such as reading, writing and mathematics. It has been shown that up to 80% of learners with learning disabilities also have reading disabilities (Kathryn, 2009). These learners find it difficult to recognize, read, or understand words. For this reason, reading disabilities impede many types of learning.

Several researchers have analyzed reading and arithmetic disabilities separately. Dyscalculia is a difficulty learning or comprehending mathematics; people with this condition find it hard to understand numbers, learn to manipulate numbers, or learn mathematical facts (Gross-Tsur et al., 1996). Although this disability is sometimes called "Arithmetic Disability" (Garnett et al., 1983), it does not include the inability to understand an arithmetic situation, even though the purpose of learning arithmetic is to be able to apply mathematical concepts in ordinary situations. Also, Problem-posing exercises are known to be an effective method of helping learners understands mathematical word problems (Silver, 1997). Thus, reading comprehension and mathematical word problems are inseparably linked. To learn a mathematical concept, a learner must understand conceptual relations, such as the relationship between quantitative concepts. But, learners with reading disabilities cannot pose problems because of their disability.

We have focused on developing a learning environment that promotes an understanding of conceptual relationships, using arithmetic word problems. We have previously confirmed that learners with reading disabilities can pose one-step addition or subtraction word problems using our

learning environment, as long as they can read a simple sentence card (Yamamoto et al., 2016; Yamamoto et al., 2017). Our system allows them to pose problems by selecting and arranging simple sentences, which are generated by the defined problem structure. We call this form of problem-posing "problem-posing as sentence integration;" the learning method is a "kit-building method" (Hirashima et al., 2016). To verify that this result does not depend on the type of problem involved, we have used the learning environment for one-step multiplication and division word problems. Also, we verify that the learning environment is effective to improve reading comprehension for learners with reading disabilities.

2. One-step Multiplication and Division Word Problems and the Learning Environment

2.1 The Structure of a One-step Multiplication and Division Word Problem

Figure 1 offers an example of a mathematical word problem that can be solved using one-step multiplication and division. The left-hand side presents an ordinary multiplication word problem. The right-hand side uses a triplet structure model to present the multiplication word problem (Hirashima et al., 2014). This arithmetic word problem consists of three simple sentences that express a quantitative concept. The sentences contain a quantity, object, and attribute. For example, in the second sentence, the quantity is six, the object is a box, and the attribute is "there are." The attribute shows different types of quantities: independent quantities express the existence of a quantity and relative quantities express the relations between quantities. The second and third simple sentence cards express independent quantities, while the first sentence card expresses a relative quantity. For example, the first sentence contains the attribute "in each." This attribute expresses the relationship between a box and an apple. We call this model the triplet structure model.

Each quantity has other meanings beyond the triplet structure model. Generally, multiplication is expressed as, "multiplicand multiplied by multiplier equals product". The quantities therefore correspond to these concepts. In Japan, the multiplicand is also called the "base quantity;" the multiplier is the "proportion;" and the product is the "compared quantity." Therefore, an arithmetic word problem that can be solved using one-step multiplication and division incorporates three types of story: (1) The compared quantity divided by the base quantity is the proportion; (2) The base quantity multiplied by the proportion is the compared quantity; (3) The compared quantity divided by the proportion is the base quantity. The story in Figure 1 is the second type of problem.
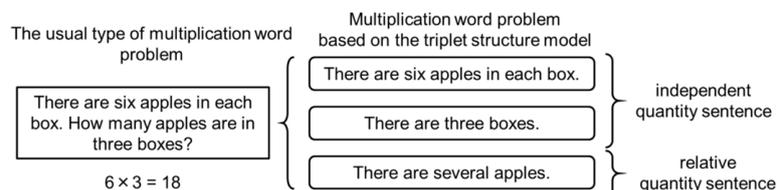

Figure 1. Presenting a Multiplication Word Problem using the Triplet Structure Model

2.2 "MONSAKUN Touch3:" The Learning Environment for Posing One-Step Multiplication and division Word Problems

A learner can learn to pose one-step multiplication and division word problems in a learning environment known as MONSAKUN Touch 3 (see Figure 2)(Yamamoto et al., 2012). MONSAKUN Touch 3 can be run on an Android tablet. In our suggested problem-posing sequence, the learner is first asked to pose the problem by selecting three simple sentence cards and arranging them in the proper order. To pose the problem, the learner must also recognize the type of quantity in each sentence and arrange the sentences in the right order.

When the three blank spaces are filled with three simple sentence cards, the diagnosis button becomes active. When the learner taps this button, MONSAKUN Touch 3 assesses the problem and generates immediate feedback. If the learner succeeds in answering all of the questions at the

selected level correctly, the interface returns to the level selection page. MONSAKUN Touch 3 offers nine levels to help learners understand the triplet structure and three kinds of quantity: "base quantity," "proportion," and "compared quantity." In Levels 1–7, MONSAKUN Touch 3 allows learners to build a story that can be resolved using one-step multiplication and division. The learner begins at Level 1 and must answer all of the questions at each level to move on to the next.
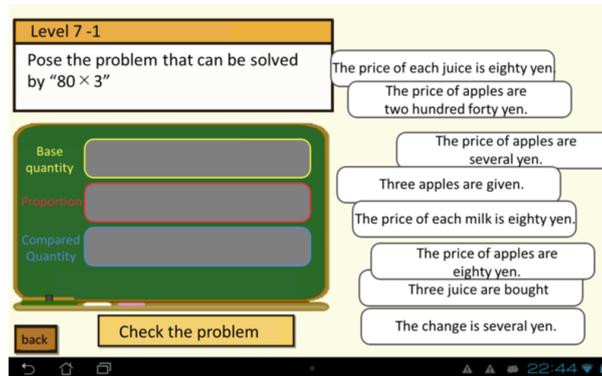

Figure 2. The Exercise Interface of MONSAKUN Touch 3.

3. Related Research

The next section describes related areas of research in reading disability. When children without learning disabilities read a story, they develop a concept of how stories are typically structured (Gersten et al., 2001). They also find it easier to develop a set of structural expectations than do children with learning disabilities, when beginning to read expository material. It is difficult for children with learning disabilities to comprehend text because they have little awareness of narrative or expository text structures (Taylor & Williams, 1983). Researchers have argued that, in order to improve learners' reading comprehension, it is necessary to teach them about text structures, using proper materials.

We also present a brief overview of learning support for arithmetic word problems, the learning subject in the present study. In a special needs classroom, teachers teach students to solve arithmetic word problems by reading the problems or showing pictures of word problems (Bender, 2007). Because it is not an arithmetic disability, studies that focus on learning to solve arithmetic word problems have not considered the issue of reading comprehension. However, in learning of arithmetic word problems, learners must find a way to learn and understand quantitative concepts and their relations, as described in Section 2.

The literature on reading comprehension suggests that improving the reading comprehension of people with learning disabilities requires a teaching method that focuses on text structures and uses proper materials. We have defined the structure of arithmetic word problems and developed a learning environment for building problems using simple sentence cards, which some learners with reading disabilities are able to read. This approach enables students to learn the structure of arithmetic word problems by posing problems through trial and error. Therefore, our learning environment does not give learners with reading disabilities to exercise the method of reading text but to build the text structure for understanding it. An understanding of the structure of arithmetic word problems can help to achieve more effective learning for reading comprehension in special needs classrooms.

4. Experimental Use

4.1 Subjects

The subjects were twelve students in a special needs classroom in a junior high school. They had already studied arithmetic word problems that could be solved using one-step multiplication and division. We divided the students into the following three groups. Seven participants did not understand simple sentences but could read simple sentences (Group A). Four participants

understood and could read simple sentences but could not read long sentences made up of more than two simple sentences (Group B). One participant could understand long sentences (Group C). These groupings reflected teacher assessments; the structure was based on previous research in which our learning environment was found to be most effective for Group B participants.

4.2 Drawing Test

We administered a drawing test to measure the participants' reading comprehension. This test is an original test, developed as a part of this learning experiment. It has been shown that learners with reading disabilities can often draw pictures to express themselves. We therefore decided that a good way of measuring their reading comprehension was to ask them to draw pictures, based on given sentences.

Drawing test consists of four levels. The subject is given several kinds of sentences or words, such as "apple;" "There are three apples." In level 1, subjects are given only one word like "apple". They are given simple sentence (Independent quantity sentence) in level 2. Level 3 assignments give subjects simple sentence (relative quantity sentence). Subjects are given multiplication and division stories which are expressed by triplet structure model in level 4. Level 4 sentences are the most difficult to read and Level 1 sentences are the easiest. The subject draws a picture, which expresses the meaning of a given word or sentence. If the subject draws a picture that accurately conveys the meaning of the sentence, it is clear that he/she has understood the given words. In such cases, the subject is considered to have answered the question correctly. There are five problems for each type of given text in the drawing test. We have assumed that participants will be able to draw more complex pictures after having the experience of learning in this learning environment.

4.3 Procedure

We used MONSAKUN Touch 3 in this experiment to verify that the kit-build method of learning was effective in helping learners with reading disabilities improve their reading comprehension performance, through the structure of arithmetic word problems. In this experiment, each subject spent one 45-minute lesson exploring the drawing test, as a pre-test experience. The subjects then spent three lessons using MONSAKUN Touch 3 to learn. In first lesson, subjects were taught the method of problem-posing for the first twenty minutes of the lesson; afterwards, they practiced using MONSAKUN Touch 3 for the remaining twenty-five minutes. Finally, the subjects practiced the drawing test for one lesson, as post-test. This experiment aimed to measure the participants' reading comprehension performance. Participants used Levels 1–7 in MONSAKUN Touch 3 because those are the levels in which subjects pose stories.

Four teachers in the special needs classroom participated in this experiment. The teachers determined, prior to the experiment, that students in Group A would not be able to practice or learn using MONSAKUN Touch 3 because they could not solve one-step multiplication and division word problems. The teachers hoped that their students would improve their reading comprehension in arithmetic word problems because the stories expressed by arithmetic word problems often involve situations that students encounter in their daily lives. We therefore suggested that the teachers use this learning method, helping the students improve their reading comprehension by visualizing and building arithmetic word problems.

As mentioned above, the present study has assumed that: (a) subjects who can understand simple sentences are also able to pose word problems that can be solved using one-step multiplication and division; and (b) subjects who can understand simple sentences are able to improve their reading comprehension by posing one-step multiplication and division word problems.

4.4 Results

This section describes the classroom environment during this experiment. Because it is difficult for learners in special needs classrooms to concentrate on learning, it is not certain that they will be able

to work on exercises like these. In this study, however, all of the subjects were able to work on the exercises without encountering any problems. Although several participants seemed to be struggling, all of them worked hard on the exercises. The teachers helped the subjects understand their mistakes when the subjects practiced, using MONSAKUN Touch 3.

The results of using MONSAKUN Touch 3 were as follows. It was not possible to carry out statistical analyses because the number of subjects was small. All of the participants concentrated on the exercises during each lesson. Group A achieved an average of Level 5; Group B achieved an average of Level 6; and Group C achieved Level 7. The average accuracy rates were 27%, 40%, and 56%, respectively, for Groups A, B, and C.

The results of the drawing test are shown in Table 1. Subjects in all groups expressed each word (Level 1) by drawing a picture. The average score for drawing independent quantity sentences was high (Level 2). However, the average score for drawing relative quantity sentences was not high (under 50%). The average score for building stories (Level 4) was high in Group C. The average score for building stories in Group B increased slightly. Meanwhile, students in Group A improved their ability to express a story. In fact, four subjects who had not been able to draw during the pre-test became able to express a story in pictures; they also improved their ability to draw pictures of relational sentences.

Table 1

Levels, Examples, and Numbers of Drawing Test Assignments

	One word		Simple sentence (Existence)		Simple sentence (Relation)		Multiplication and division Story	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Group A	5	5	4	3.71	1.14	1.71	0.71	1.14
Group B	5	5	4.25	4.25	2.25	1.5	2	2.25
Group C	5	5	5	5	3	3	4	4
Total	5	5	4.17	4	1.67	1.75	1.42	1.75

4.5 Discussion

This section analyzes which subjects were able to pose one-step multiplication and division word problems, using our learning environment. Each learner was then given an average of 8 sentence cards in our learning environment. As 336 problems could potentially be posed, it was impossible to complete the assignment randomly and correctly. The results of the problem-posing exercise using MONSAKUN Touch 3 showed that subjects in each group were able to pose problems with a higher than 30% accuracy rate. Given that the participants in this study all had learning disabilities, the accuracy rates of each group were not low. It is worth noting that, on another occasion, we administered a problem-posing test in which the same subjects were asked to pose problems by writing out one-step multiplication and division word problems; none of the subjects could write a these word problem in proper because the cognitive load was too heavy.

This study shows that learners with reading disabilities can pose problems that can be solved using one-step multiplication and division within our learning environment. Surprisingly, even members of Group A, whom the teachers felt could not understand simple sentences, were able to pose problems. They also improved their score of drawing test. Since it is very difficult to accurately assess the degree of a learning disability, our system may help to measure this. We would also argue that the kit-build method may be effective at helping learners with reading disabilities to learn the structure of problems through trial and error in a wide range of domains.

The drawing test produced interesting results. Participants in Group A improved their drawing performance. This suggests that our learning environment may be particularly effective at helping students with relatively severe disabilities improve their reading comprehension. Overall, four participants improved their scores for drawing stories: three in Group A and one in Group B. These subjects also improved their ability to draw pictures to express relational sentences. This results show that it is important for students to understand both independent quantity sentences and relative quantity sentences to improve their reading comprehension of arithmetic word problems.

Our results suggest that learners cannot understand arithmetic stories unless they also understand the meaning of each simple sentence and the relationship between simple sentences.

5. Conclusions

This paper demonstrates the practical value of using an interactive environment to help students with reading disabilities in a special needs classroom learn to pose one-step multiplication and division word problems. The students used simple sentence cards, which were generated by the problem structure that we defined. The present study also aimed to confirm that the kit-building materials we developed could help students improve their reading comprehension using arithmetic word problems.

As the results, A drawing test, in which learners were asked to draw illustrations of presented sentences, confirmed the extent to which each learner understood the meaning of the sentences. The results of log analysis confirmed that our method of structuring and assembling sentences can improve reading comprehension in special needs classrooms.

Future research should include a more detailed analysis of these results, and define the relationship between the features of various learning disabilities and models of arithmetic word problems.

Acknowledgements

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