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Design of Meta-Problem with Open Information Structure Approach

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Abstract: We have designed a task to pose a word problem by selecting and combining adequate quantity propositions that are provided. The problem posing task requires learners to think about their problem-solving of the word problems. We, therefore, call the problem-posing task "meta-problem" for the original word problem. In the design of the problem-posing task, we modeled the word problem as a structure composed of several quantity propositions, and defined the task as a reconstruction of an adequate structure by combining several quantity propositions. We call the design method "open information structure approach". This approach that we successfully applied to arithmetic word problems has potential as a general method to design meta-problems from an original problem and to realize automatic diagnosis and feedback to support the solving process of the meta-problem. The problem-posing task in the arithmetic word problem as an example of a design of meta-problem with open information structure approach is explained.

Keywords: Meta-Problem, Metacognition, Open Information Structure Approach, Arithmetic Word Problem

1. Introduction

In order to realize fruitful learning effect of problem-solving exercise, metacognition by learners themselves for the problem-solving plays a crucial role (Hacker 1998; Hartman 1998). Many investigations of technology-enhance learning have already focused on promoting metacognitive activities of a learner (Kapa 2001; Leelawong 2008; Kashihara 2008; Seta 2015) and designed their own meta-problems. However, both diagnosis of the process of solving the meta-problems and support for the process based on the diagnosis have been difficult issues yet. In this paper, design of meta-problem with open information structure approach is introduced as a solution of the issues.

In our previous researches (Hirashima 2007), we have designed "problem-posing task" in arithmetic word problems with automatic diagnosis and feedback functions. In the problem-posing task, learners are provided components of the arithmetic word problems, and required to reconstruct an adequate problem by combining several components. Because the problem-posing task promote learners to think about their problem-solving, the task is a kind of meta-problem. Then, because the task is defined as selection and combination of predefined components, diagnosis and support for the solving process have already been realized. In this design method of meta-problem, because learners are allowed to operate components of a model of a learning target, that is, an arithmetic word problem in this case, we call this method "open information structure approach". Carbonell proposed "information structure oriented approach" that designs learning tasks in an intelligent tutoring system based on well-defined information structure of a learning target (Carbonell 1970). Because we allow leaners to directly operate the structure, we call the approach "open information structure".

The open information structure approach that we successfully applied to arithmetic word problems has potential as a general method to design meta-problems from an original problem and to realize automatic diagnosis and feedback to support the solving process of the meta-problem. In this paper, as a preliminary step to extend the design method to general one, we try to explain the problem-posing task in the arithmetic word problem as an example of a design of meta-problem with open information structure approach.

2. A Model of Information Structure of Arithmetic Word Problem

Our problem-posing task is designed based on a model of arithmetic word problems "triplet quantity proposition model" (Hirashima 2014). Figure 1 shows an example of a basic unit story and problem. Here, a story is a language expression not including unknown quantity. The story is composed of three sentences and each sentence corresponds to each quantity proposition. The relative quantity proposition expresses the relation between two independent quantity propositions. The mathematical expression derived from the story is called story numerical expression. When one of the three quantities is changed to unknown, the story becomes a problem that can be solved with other two quantities. From a basic unit story, three basic unit problems are made. A basic problem is shown in right side of Figure 1. A problem has two numerical expressions, one is problem numerical expression and the other is calculation numerical expression. When problem numerical expression and calculation numerical expression are the same expressions, the problem is called forward thinking problem. When they are not the same ones, the problem is called reverse thinking problem. A reverse thinking problem is much more difficult than a forward thinking problem.

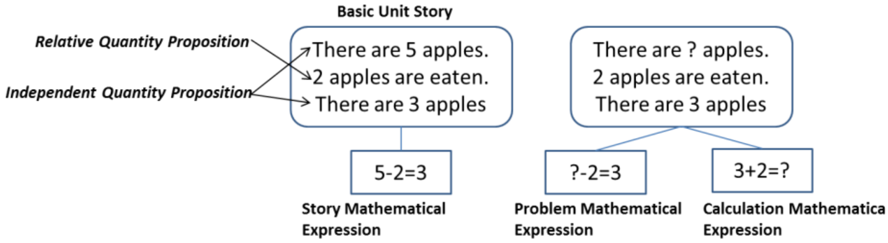

Figure 1. Basic Unit Story/Problem

Figure 2 shows that from an independent quantity proposition all kinds of problem/story can be generated. In Figure 2, "there are 6 apples" is used as a smaller number of the apples in an increase story. In a decrease story, then, it is used as a larger number of the apples. By using with "there are 3 oranges", "there are 6 apples" is used in a combination story, more than story and less than story. The independent quantity proposition is also used in multiplication by combining with relative quantity sentence of multiplication as shown in the right side of Figure 2. Here, "one apple is 80 cents" is a relative quantity proposition that expresses a relation between the number of apples and the number of cents (money). "2 apples on a dish" is also a relative quantity proposition but in this case, the "6 (apple)" is divided by this 2 (apple/dish).

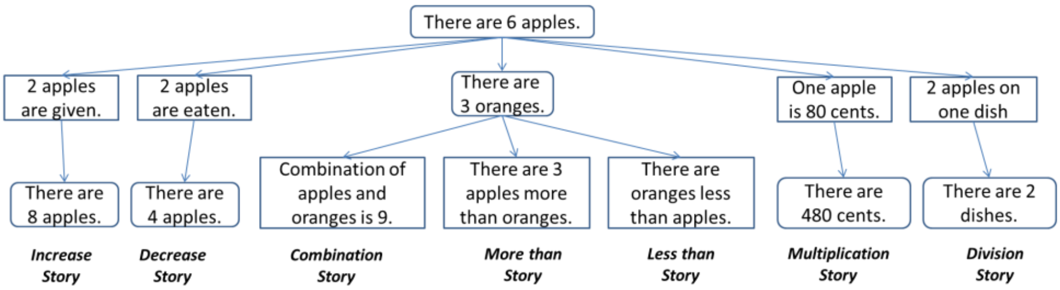

Figure 2. Various Combinations of Three Propositions

3. Problem-Posing as a Meta-Problem

Triplet Quantity Proposition Model provides components of arithmetic word problem. Based on model, it is possible to design various tasks to operate the components. Because the tasks allow learners to operate instance of information structure of arithmetic word problem, we call this approach "open information structure", and then, because the task promotes learners to reflect their problem-solving, we call the task "meta-problem".

Problem-posing designed based on the model is introduced with Figure 3. In the upper left side of the interface, a calculation “7-3” and a type of arithmetic story (change problem: increase) are assigned. A learner is required to pose a problem that can be solved by the calculation and belongs to the specific type of an arithmetic problem by using sentence cards provided in the right side of the interface. Each sentence card expresses a quantity proposition. The set of sentence cards includes not only the necessary ones but also unnecessary ones. In the lower left side, there are three blanks where a learner puts sentence cards in order to complete a problem. In Figure 3, two cards have been put in the blanks. In this case, correct problem is composed of {“Tom has 3 pencils.” “Tom buys several pencils.” “Tom has 7 pencils.”}. By pushing the “Check the problem” button, the posed problem is diagnosed and the learner is able to receive feedback based on the diagnosis.

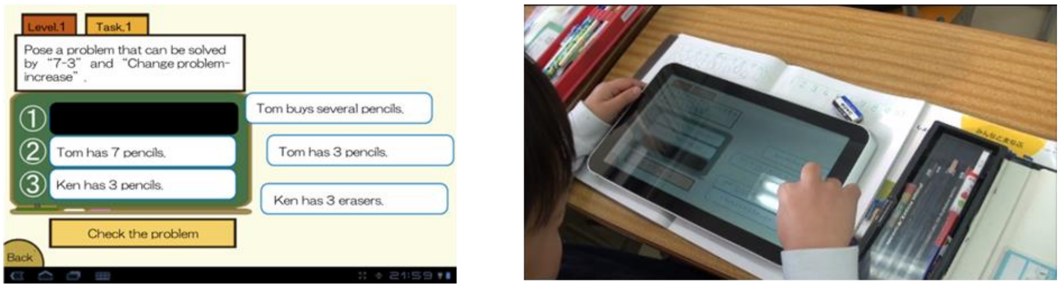

Figure 3. Workspace of Problem-Posing and a Scene of Practical Use

In the problem-posing, learners is requested to (1) select of sentence cards and (2) order the selected sentence cards to complete an information structure of an arithmetic word problem. In other words, the learners operate information structure of an arithmetic word problem by operating sentence cards. Therefore, the problem-posing is an example of meta-problem designed based on an information structure by allowing learners to operate the structure. An interactive environment for the problem-posing has been also implemented and practically used as shown in Figure 3.

4. Conclusion Remarks

As a desing of meta-problem with open information structure approach, problem-posing was introduced. As our future work, it is necessary to develop various kinds of meta-problem based on the information structure in arithmetic word problem and to apply this approach for various learning domains, in order to verify contributions of open information structure approach.

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