Analysis of Problem-Posing Process of Arithmetical Word Problem as Sentence Integration: Viewpoint of First Selected Sentence

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Abstract. We have developed tablet PC-based software for learning by posing arithmetical word problems named MONSAKUN where several sentences are integrated to pose a problem by a learner. We call this type of problem-posing "sentence integration". Based on collected data by past experimental use, we have been analyzing users' problem-posing process as the selection process of the sentences. As the first step of this analysis, we found that the first sentence selected in the process were different in (1) type of approach, (2) type of story and (3) exercise experience. These results are important to make an elaborate process model of the problem-posing and adaptive support of the process.

Keywords: Problem posing, arithmetical word problems, sentence integration, reverse thinking problem, learning analytics

1 Introduction

Learning by problem-posing is well known as an alternative and important way to promote learners' understanding in solving arithmetic problems [1,2]. To realize learning by problem-posing in a practical way, we developed a computer-based learning environment [3]. The software, named MONSAKUN ("Problem-posing Boy"), provides an interactive support for learning arithmetical word problems solved by one operation of addition/subtraction.

The interface of MONSAKUN is explained in Figure 1. A learner is provided with a set of sentence cards and a numerical expression, and then he/she is required to pose an arithmetical word problem by selecting and arranging appropriate cards. Each card contains a number from the provided numerical expression (first, second, or third number). There are four story types in the exercise: combination, increase, decrease, and comparison. Although learners do not create their own problem statements, they are required to interpret the provided sentences and integrate them into one problem, which is the same as ordinary problem-posing activity in essence. This activity is called "problem-posing as sentence-integration" [4].

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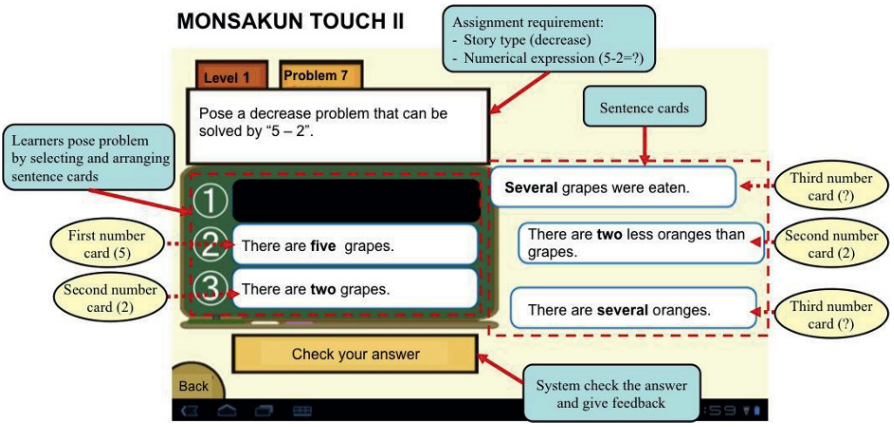

Fig. 1. Interface of MONSAKUN

The practical use of MONSAKUN at several elementary schools has been reported in previous studies [3,4,5]. It has been confirmed that the exercise is effective to improve both problem-posing and problem-categorization abilities. Students and teachers also enjoyed using this system and considered it useful for learning.

While it is difficult to analyze thinking process in a free problem posing activity, we can trace learners' card selection in MONSAKUN which can be considered to reflect their thinking process. In this study, we examine how learners pose arithmetical word problems as sentence integration on MONSAKUN. Our assumption is that learners do not choose sentence cards randomly, but based on some sort of thinking. As the first step toward analyzing problem-posing activity, we especially focus on the type of firstly selected sentence card in each assignment.

2 Analysis of MONSAKUN Log Data

2.1 Difference in First Selected Card between Level 1 (Forward-thinking Problems) and Level 5 (Reverse-thinking Problems)

In this study, the log data of 11 university students using MONSAKUN is analyzed. We focused on subjects' log data in assignments at Level 1 and Level 5 which require them to pose forward-thinking problems and reverse-thinking problems, respectively. In forward-thinking problem, a story represented in the problem has the same structure with the calculation to derive the answer. This type of problem can usually be solved easily by the learners. In reverse-thinking problem, the story and the calculation operation structures are different, so learners are required to understand the problem structure well to pose this kind of problem.

Table 1 shows the proportion of first card chosen by subjects in Level 1 and 5. From the analysis, we found that the proportion of each sentence card to be selected firstly is not even. This shows that subjects did not choose a card randomly, but with some sort of approach.

Table 1 Percentage of first selected card by the subjects

Type of first selected card	Level 1 (%)	Level 5 (%)
First number card	91.8	58.7
Second number card	3.3	16.5
Third number card (question mark)	4.9	24.8

Furthermore, there are different trends between Level 1 and 5. We presume that subjects had different approach to pose either forward-thinking or reverse-thinking problems. In forward-thinking problem, the approach to choose cards by the order of numbers in the numerical expression can be applied easily. However, in reverse-thinking problem they cannot easily pose problem with the same approach. This type of problem requires learners to think about the numerical relation in the given problem and reflect it to the choice of cards.

2.2 Change of Approach through the Exercise

In this section, we would like to explain further how the subjects change their way of thinking during problem posing exercise by looking at the type of story, order of assignment, type of first selected card, as well as the type of sentence.

Table 2 shows the characteristics of first selected card from each assignment at Level 5 that has marginal/significant difference in number of selection from the average. These results were analyzed with binomial test to the amount of each card chosen in each assignment. Based on our assumption that students posed problems by selecting cards through a thinking process, we expect the distribution of first selected card to have a significant difference in comparison with other cards.

During simple forward-thinking problems exercise at Level 1, we found that subjects' initial approach is to simply choose a card with the first number in the required numerical expression. In reverse-thinking problems exercise at Level 5, they firstly did the assignment with the same initial approach. However, this did not work well, and they tend to make more mistakes than in the previous levels. We presumed that the subjects were aware that the previous approach of choosing first number card did not work for reverse-thinking problems, because in the second assignment of Level 5 they tend to choose another type of card. We could observe from Table 2 that subjects changed their approach from the first assignment in a type of story to the second and third assignment in the same type of story.

This leads to two findings about changes in subjects' way of thinking through the exercises. The first one is that subjects change their approach to pose problems after they had experienced posing the same type of story. The next finding is that the change of approach depends on the type of story, as we can see that subjects made different first card selection in different story type.

Table 2. Result of binomial test of first selected card in Level 5 assignments

No	Type of story	Order of assignment	Type of first selected card	Type of sentence	p-value	
1	**Combination**	1st	*First number card*	*Existence*	$7.05*10^{-5}$	**
2		2nd	First number card	Relational	$1.88*10^{-7}$	**
3		3rd	First number card	Relational	$1.97*10^{-3}$	**
4	**Increase**	1st	*First number card*	*Existence*	$1.89*10^{-5}$	**
5		2nd	Second number card	Existence	0.0504	+
6		3rd	*First number card*	*Existence*	0.0504	+
7	**Decrease**	1st	*First number card*	*Existence*	$2.35*10^{-4}$	**
8		2nd	Second number card	Existence	$2.35*10^{-4}$	**
9		3rd	Second number card	Existence	$2.35*10^{-4}$	**
10	**Comparison**	1st	-	-	-	
11		2nd	Third number card	Relational	0.0266	*
12		3rd	Third number card	Relational	0.0266	*

**: significant difference ($p<.01$), *: significant difference ($p<.05$), +:, marginal difference ($p<.1$)

3 Concluding Remarks

In this research, we have conducted analysis of university students' problem posing activity to investigate their way of thinking in posing arithmetical word problems. From the analysis, we found that the first sentence selected in each assignment were different in several ways depending on the type of story and subjects' exercise experience. Furthermore, we infer that users of MONSAKUN were able to recognize the differences in problem structure depending on type of story, as they changed their approach to pose problems for different story types.

For the next step of this research, we plan to perform the analysis to a larger data of MONSAKUN use by elementary school students. The result will be used to make an elaborate process model of problem-posing and adaptive support of the process.

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