Ogata, H. et al. (Eds.) (2015). Proceedings of the 23rd International Conference on Computers in Education. China: Asia-Pacific Society for Computers in Education

Investigation of Students' Performance in Monsakun Problem Posing Activity based on the Triplet Structure Model of Arithmetical Word Problems

Nur HASANAH[a*], Yusuke HAYASHI[a] & Tsukasa HIRASHIMA[a]
[a]*Dept. of Information Engineering, Hiroshima University, Japan*
*nur@lel.hiroshima-u.ac.jp

Abstract: The implementation of learning by problem posing in practical use is facing the issue of inefficiency in time needed for assessment and giving feedback to students' posed problems. As a solution of this problem, we have developed tablet PC-based software for learning by posing arithmetical word problems named Monsakun. The software is based on Triplet Structure Model of arithmetical word problem. In this research, we investigated elementary school students' performance in Monsakun. The result shows that students did not pose problems randomly and with some sort of thinking. With further analysis of constraints, we also found that the frequent errors contain few non-meaningful errors and students tried to pose problems satisfying as many constraints required in each assignment as possible. The process of understanding assignment requirements and relating them to suitable sentence cards is an important point especially for young learners to reach deep understanding of the structure of arithmetical word problems.

Keywords: Problem posing, arithmetical word problems, elementary school students, learning analytics

1. Introduction

Learning by problem posing is one of central themes in mathematics education that has been suggested as an important way to promote learner's understanding (Ellerton, 1986; Polya, 1957). The practice of problem posing is different than the usual practice of teaching by solving pre-formulated problems, in the way of encouraging learners to generate new problems (Silver & Cai, 1996). It is one of the important foundations of reformation in mathematics educations, and the realization of its importance has lead into growing research of various aspects in activities of learning by problem posing (English, 2003).

The implementation of learning by problem posing in practical use is facing the issue of inefficiency in time needed for assessment and giving feedback to students' posed problems. While students found difficulty in posing mathematically correct problems in a satisfying amount in a given time, teachers were having problems of limited time for assessing students' work during class activity. These problems are the main reason of the unpopularity of problem posing activity, despite its importance in building deeper understanding of mathematical problems for the students.

To address this issue, we have developed a computer-based learning environment to realize learning by problem-posing in a practical way for one operation of addition and subtraction. The software, named Monsakun (means "Problem-posing Boy" in Japanese), enables the process of assessment and giving feedback to students' posed problems automatically, and teacher could monitor students' progress individually as well as all students in a classroom in a real time (Hirashima et al, 2007; Kurayama & Hirashima, 2010). Figure 1 shows the interface of an assignment in Monsakun. A learner is provided with a set of sentence cards and a numerical expression, then he pose an arithmetical word problem using the numerical expression by selecting and arranging appropriate cards. In the problem posing activity, learners do not create their own problem statements, however they are required to interpret the sentences cards and integrate them into one problem. This activity is called "problem-posing as sentence-integration" (Hirashima & Kurayama, 2011).

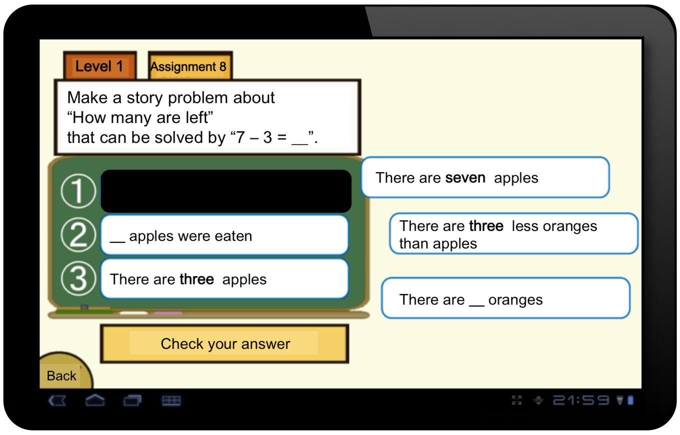

Figure 1. Interface of Monsakun

The practical use of Monsakun at several elementary schools has been reported in previous studies (Hirashima et al., 2008; Yamamoto et al., 2013). The effect of learning by problem-posing with Monsakun was investigated by the analysis of pre-test and post-test of high-score group and low-score group of the students. As a result, it has been confirmed that problem-posing exercise using Monsakun is effective to improve both problem-posing and problem-categorization abilities. Furthermore, after long term use of Monsakun in an elementary school, the result showed that both the students and teachers enjoyed using this system continuously and considered it useful for learning.

Solving problem does not imply understanding of the problem. Using Monsakun as a problem-posing learning environment, we promote students not only to solve problems, but also to understand them. Our software is a novel way to promote learning by problem posing and has different aspects from other practice of problem posing activity. Through previous researches, the usefulness of Monsakun has been confirmed for learning by problem posing. However, it is necessary to justify the validity of problem posing activity in Monsakun.

There are two main points that explains the necessity of the justification: First, in Monsakun, the process of posing problem is conducted by combination of given parts. Thus, theoretically, it is possible for students to pose problems in random way, which means that they are not engaged in some sort of thinking process when posing problems. On the other hand, our aim in developing this system is to promote students’ logical ability and thinking through posing problems instead of only solving problems..Therefore, we conducted this study to prove that students do not pose problem in random way, but with some sort of thinking.

Second, we have developed a new model called “Triplet Structure Model”, which describes an arithmetic word problem structure in sentence-integration process, and this model is the base of our software Monsakun (Hirashima et al, 2014). This model is proposed in order to break down the assessment process of posing problem of simple arithmetic word problems. From this model, we break down the task model of problem posing and define the types of constraint that needs to be satisfied in problem posing by Monsakun. However, as this model is new, it is necessary to conduct investigation of students’ performance in Monsakun related to the Triplet Structure Model, that is, we want to show that students’ selection of cards, the difficulty level, the appearance of different and meaningful error types, and the satisfied constraints, are explainable with our model.

Previous studies have been conducted to investigate university students’ thinking process when using Monsakun (Hasanah, Hayashi & Hirashima, 2014a-b). In this paper, we conducted analysis of elementary school students’ performance during problem posing activities using Monsakun based on two main research questions. The research questions are 1) Whether students pose problems randomly, in relation to the natural possibility of this software; and 2) Whether the appearance of posed problems by students can be explained by the triplet structure model. This study is limited only to the type of word problems used in Monsakun.

The composition of this paper is as follows. The next section gives an overview of Monsakun, the definition of problem types, and the Triplet Structure Model. Section 3 explains the practical use and the analysis of elementary school students’ performance in accordance to our research paper. Finally section 4 concludes this paper and shows some prospects for future study.

2. Monsakun as Learning Environment for Problem Posing

2.1 Triplet Structure Model

Triplet structure model, as shown in Figure 2, describes the meaning of different quantities in arithmetical word problems and how they compose different types of problem. An arithmetic word problem solved by addition or subtraction is composed of two "independent quantity sentences" and one "relative quantity sentence". The combination of different sentences creates different role for each of the sentence (Hirashima et al, 2014).

There are two types of numerical relation in arithmetic word problems: "problem numerical relation" and "calculation numerical relation". In this example, [There are 5 apples. 2 apples are eaten. There are "?" apples.], to derive the answer, the calculation is 5-2, and the answer is 3. According to the triplet structure model, the problem numerical relation is "5-2=?", and the calculation numerical relation is also the same. This type of problem is called "forward thinking problem".

Meanwhile, in the following example, [There are "?" apples. 2 apples are eaten. There are 3 apples.], to derive the answer, the calculation is 2+3, and the answer is 5. According to the triplet structure model, the problem numerical relation is "?-2=3", while the calculation numerical relation is "2+3=5". This type of problem, where the calculation and problem numerical relation are different, is called "reverse thinking problem". This type of problem is more difficult for students than forward thinking problems, because the student is required not only to understand the story, but also to derive the calculation from the story.

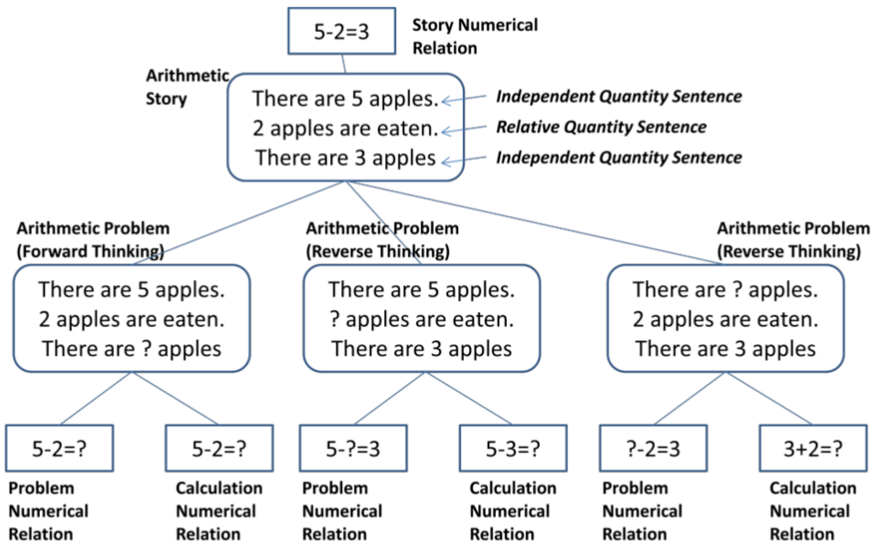

Figure 2. Triplet Structure Model (Hirashima et al, 2014)

2.2 Definition of Story Types

There are two types of sentences in arithmetical word problems: existence sentence and relational sentence. An *existence sentence* represents a number of single objects that has an independent quantity. A *relational sentence* has a relative quantity and contains keyword that represents a story type. An arithmetic word problem of binary operation is integration of two existence sentences and one relational sentence.

There are four types of story in arithmetic word problems of addition and subtraction: 1) combination, 2) increase, 3) decrease, and 4) comparison (Riley, Greeno and Heller, 1983). In Monsakun, the differences among them are defined as differences of integration of sentences. For example, a combination story type problem is composed as follows:

a) There are seven apples *(existence sentence)*,
b) There are three oranges *(existence sentence)*, and
c) There are ten apples and oranges in total *(relational sentence with combination story type).*

2.3 Types of Constraints based on Task Model of Problem-Posing

The task model of problem posing as sentence-integration has been developed based on the consideration of problem types in the Triplet Structure Model, as shown in Figure 3 (Kurayama & Hirashima, 2010). There are four main tasks in problem posing activity: (1) deciding calculation operation structure, (2) deciding story operation structure, (3) deciding story structure, and (4) deciding problem sentences. A learner should complete these tasks to pose a correct problem, although the execution procedure of the tasks is not decided in the model.

In the first step of Monsakun, subtraction or addition is selected as a *calculation operation*. In the second step, a story operation structure is decided. For example, for subtraction, four story operation structures can be selected. Among them, only one story operation structure is the same with the calculation operation structure (subtraction), and two of them have completely different story operation, that is, addition. Because this is an abstract transformation, it is often very difficult for learners to decide.

The next task of deciding *story structure* involves selection from four types of story: combination, increase, decrease, or comparison problem. Each type of story has its own structure, as explained in the sections above.

In the last task of deciding *problem sentences*, sentences are put into the story structure following the story operation structure. This task is divided into three more tasks: deciding sentence structure, deciding concept structure and deciding number structure.

Deciding *sentence structure* is to select and order sentences following the story structure. For example, if the story structure is the decrease type, learner should make a sentence structure composed of an existence sentence, a decrease sentence, then followed by another existence sentence. For the decision of *concept structure*, concepts dealt with the problem are decided. For example, if the problem requested learner to answer about the total number of apples and oranges, then the sentences should be dealt with apples and oranges as the concept. For the decision of *number structure*, the numbers dealt with the problem is decided. In arithmetic word problems, a negative number should not be used.

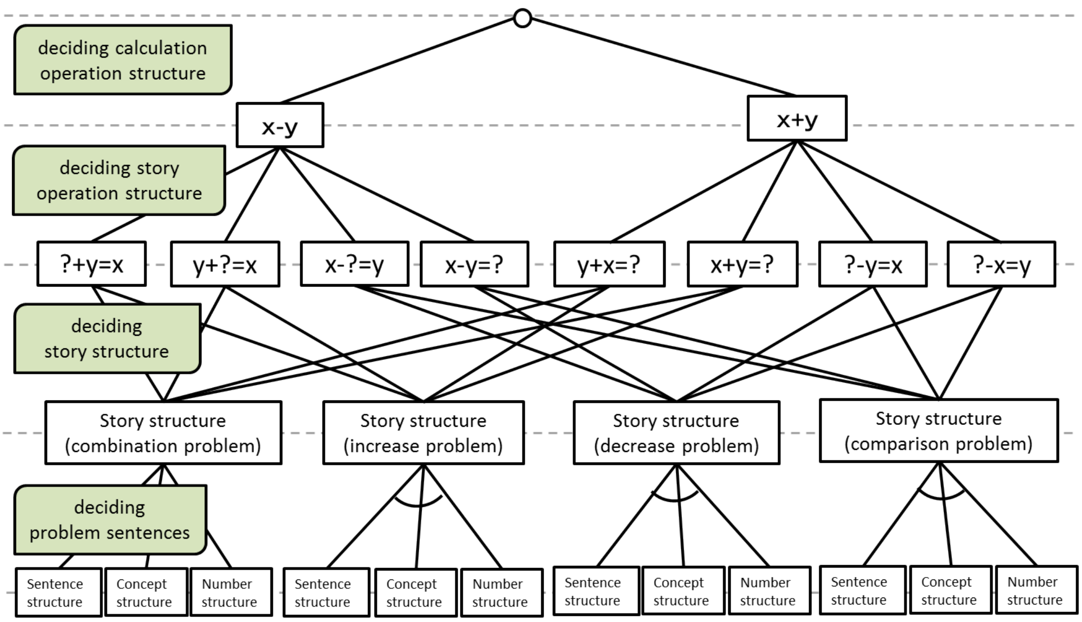

Figure 3. Task model of problem-posing as sentence integration

For example, we will look at the assignment in Figure 1. The first step of deciding calculation operation structure is conducted by reading the assignment. The requirement is to make a problem about "how many are left" that can be solved by "7-3", so the learner would naturally decides the calculation structure is "7-3". The next step is deciding story operation structure. There are four possible structure, which should be determined by looking at the provided sentence cards. The structure “x-?=y” or “x-y=?” could either satisfy the requirement. Then the learner decides the story structure by looking at the requirement, "how many are left", which indicates a decrease problem. In the last step of deciding problem sentences, the learner needs to select appropriate three sentence cards and put them in correct order that satisfies the concept, number, and sentence structure. In this case, the numbers needed are 7, 3, and blank. The concept/object needed is only one (apple), because this is a decrease problem that only need one object, not a comparison problem that needs two objects. Then, the sentence needed are firstly an existence sentence that indicates the initial number, followed by a relational sentence with decrease story type, and thirdly an existence sentence that indicates the resulting number. Therefore, by looking at the provided sentence cards, the correct problem would be (A) There are 7 apples, (B) ... apples were eaten, (C) There are 3 apples.

Based on the task model, we have devised five main constraints to be satisfied by each posed problems, which are: 1) Calculation, 2) Story type, 3) Number, 4) Concepts/Objects, and 5) Sentence structure. When all five constraints are satisfied, then the learner has succeeded in posing a correct problem which satisfies the assignment requirements. When less than five constraints are satisfied, it shows that the learner has acquired a level of understanding in the structure of arithmetic word problem, however the final problem does not satisfy the requirements yet. If there are no constraints satisfied by the learner, it shows that the learner is unable to understand the structure of arithmetic word problem. These definitions of constraints are important for the analysis in this study.

2.4 Assessment of Errors

According to the task model of problem posing in Monsakun, errors in posing problems are identified into seven categories, which are: (1) Different story type, (2) Different calculation formula, (3) Different story and calculation, (4) Error of object, (5) Error of value/numbers, (6) Error of object & value, and (7) Story isn't built. The flowchart of error assessment is shown in Figure 4. When students make incorrect problems, the system gives a feedback message in accordance to the type of error that the student committed.

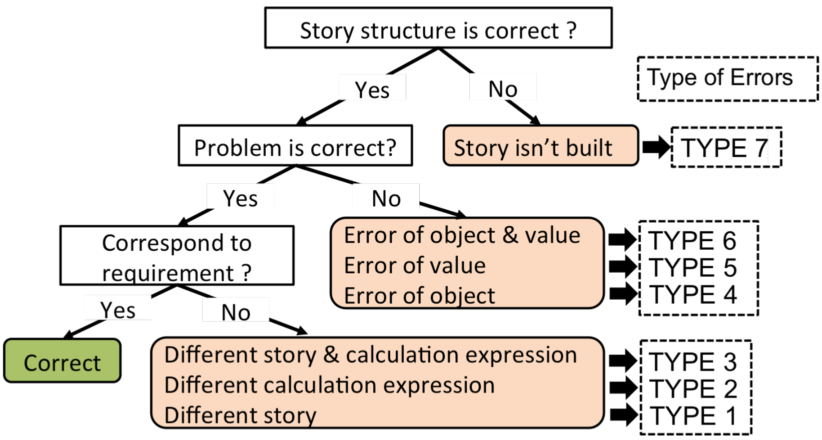

Figure 4. Flowchart of error assessment in Monsakun

3. Analysis of Students' Performance in Monsakun

In this section, the analysis of Monsakun log data from a practical use of Monsakun in a classroom of 39 first grade elementary school students from Hiroshima Fuzoku Elementary School is reported. The practical use consist of 9 class sessions, where each session starts by Monsakun use for 5 minutes, usual classroom teaching activity for 35 minutes, and concluded by Monsakun use for 5 minutes. The teacher is involved in every session. The teacher monitored students' progress real time using Monsakun Analyzer and gave assistance to students who seem to have difficulties in progressing with Monsakun task. During the teaching activity, the teacher provided one assignment to all students that resembled problem posing process in Monsakun and encouraged participation and active discussion from all students to pose the correct problem together.

During 9 class sessions, students practiced using different levels in Monsakun. Level 1, 3, and 5 were used in two class sessions, respectively, while Level 2 and 4 only practiced in one class session. Level 1, 3, and 5 consist of 12 assignments that include four types of stories: combination, increase, decrease, and comparison. Each type of story has three assignments. Subjects carried out the assignments in order, and they can only move on to the next assignment when the current assignment has been answered correctly. In Level 1, subjects are given problem formula and required to pose forward thinking problem. This is the easiest assignments in Monsakun. In Level 3, subjects are given problem formula and required to pose reverse thinking problem. Although the problem requires different thinking approach, it is still considered easy for the subjects. In Level 5, subjects are given calculation formula and required to pose reverse thinking problem. This is the most challenging assignments in Monsakun.

We analyzed the subjects' log data in assignments at Level 1, Level 3, and Level 5 to find out students' performance. We do not include Level 2 and Level 4 in the analysis, because they only consist of three assignments each, and our initial observation shows no significant effect of excluding them from subjects' overall performance.

3.1 Comparison of Students' Performance in Level 1, Level 3, and Level 5

First, to understand students' performance in posing problems with different requirements, we investigated the rate of finished students and the average or steps and mistakes in each level. The result is shown in Figure 5.

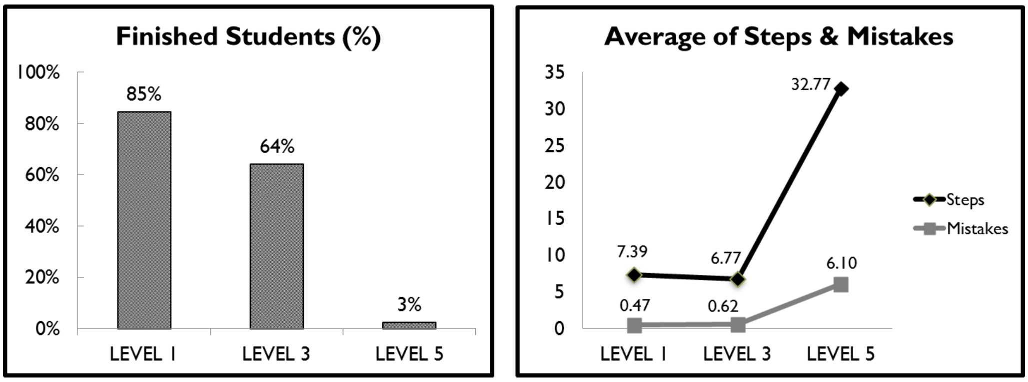

Figure 5. Comparison of Students' Performance in Level 1, Level 3, and Level 5

Counting the first time students posed problem in each level, 85% of students were able to pose all assignments in Level 1 correctly, and 64% finished Level 3. In contrast, the number of students who finished all assignments in Level 5 decreased very rapidly compared to Level 1 and 3.

The average of steps and mistakes shows how many steps a student needed in order to pose a correct problem in one assignment, and how many mistakes he made during the process. Ideally, a student would only need 3 steps to pose a correct problem, because a problem in Monsakun consists of the arrangement of 3 simple sentence cards. As shown in Figure 5, the average of steps in Level 3 was slightly lower than Level 1, even though the average of mistakes was slightly higher, which suggests that students learned to select cards more effectively by learning from their mistakes. However, the average in Level 5 was very high compared to Level 1 and Level 3, which shows that Level 5 was indeed very challenging for students.

Next, we look at the types of error students made during their first time posed problem in each level. The frequency of error types are shown in Table 1 (actual amount) and Figure 6 (graph). We found out that students made 11.2x more mistakes in Level 5 than their average mistakes in Level 1 and Level 3. In all three levels, the dominant errors are Type 7 ("Story is not built"). It comprised of 50-60% of all mistakes. The rest are combination of Type 1-6, which are classified as meaningful errors. However, further analysis shows that by looking at satisfied constraints in error Type 7, some of them are meaningful errors, that is even though the sentence cards does not form a correct arithmetic problem, some of the constraints are met. The analysis of satisfied constraints is reported in section 3.3.

Table 1. Frequency of Error Types in Level 1, Level 3, and Level 5 (actual amount)

Error Type	Level			Total
	1	3	5	
(1) Different story type	1	15	288	304
(2) Different calculation formula	26	38	283	347
(3) Different story and calculation	0	0	89	89
(4) Error of object	9	36	39	84
(5) Error of value/numbers	45	46	395	486
(6) Error of object & value	13	15	134	162
(7) Story isn't built	126	139	1625	1890
Total	220	289	2853	3362

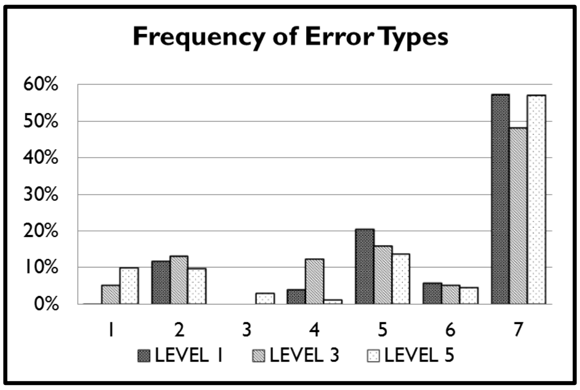

Figure 6. Frequency of error types in Level 1, Level 3, and Level 5 (graph)

3.2 Analysis of Students' Performance in Level 5

From the analysis in the previous section, students seem to struggle hard when they are given reverse thinking problems with provided calculation formula as in Level 5, in contrast of provided story formula as in Level 1 and Level 3. In this section, the result of further analysis of students' performance in Level 5 is explained. The analysis consists of: (1) Steps and mistakes in different story type, (2) Correlation analysis between possible and actual errors, and (3) Correlation analysis between possible and actual satisfied constraints (section 3.3). The result of these analyses will provide some answers to our research questions.

Figure 7 shows the graph of average steps and mistakes in Level 5 in different story type. There are four story types in arithmetic word problem: combination, increase, decrease, and comparison. Students are given three assignments for each story type, therefore assignments no. 1-3 are combination problems; assignments no. 4-6 are increase problems, and so on. We look at the average steps and mistakes in each story type by distinguishing between the first time a student pose problem in one story type and the second/third time, in consideration that a student will need to re-adjust their thinking when first time posing a different story type, thus we assume that he would learn the problem structure in the second and third assignments in the same story type.

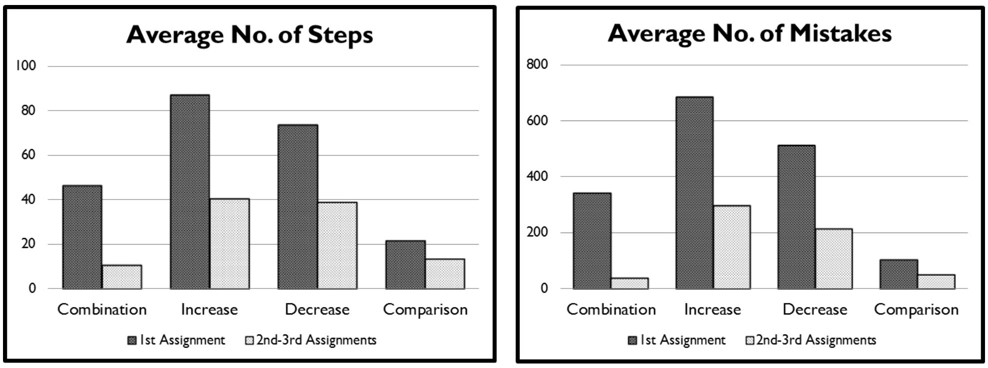

Figure 7. Average number of steps and mistakes in different story types in Level 5

As shown in Figure 7, in comparison of the first assignment in each story type, the average of steps and mistakes in the second and third assignments of the same story type are lower. This finding reflects that during the problem posing exercise using Monsakun, students were able to make a progress by learning how to pose different story types, thus this shows that they did not pose problems randomly, but with some sort of understanding.

Despite the nature of this learning system that could permit students to select three sentence cards randomly, students' intention to pose problems according to the given requirements is further explained through the correlation analysis between possible and actual error counts in Level 5.

In Monsakun, five or six sentence cards are provided in each assignment. Three of them are correct cards, which satisfy all constraints from the assignment requirement and when ordered correctly will form the correct problem. The rest are dummy cards, which designed through careful considerations by the expert as a meaningful distraction to the students in order to learn the structure of simple arithmetic word problem. Thus, for assignments with 6 sentence cards, there are ${}_6P_3 = 120$ possible card combinations, and for assignments with 5 sentence cards, there are ${}_5P_3 = 60$ possible card combinations. Each card combination is checked whether it is the correct answer or incorrect answer, and if it is incorrect, Monsakun automatically diagnose the type of error.

Table 2. Correlation between Possible and Actual Errors in Level 5

Assignment	Error Types							Possible vs Actual	
	1	2	3	4	5	6	7	Chi-Sq	p
1	**			ns	ns	ns	+	0.009173	**
2		**		+	ns	*	*	0.000009966	**
3	*				ns	**	ns	0.003101	**
4	ns	**			ns		**	0.006	**
5		**			ns		**	0.001	**
6	*		+		ns		**	0.008	**
7	ns	ns	ns		ns		ns	0.066	+
8		*			ns		**	0.019	*
9	ns	ns	ns		ns		ns	0.062	+
10	**				ns	*	ns	0.005946	**
11		**		ns	ns	ns	**	4.337E-09	**
12	**			*	**	**	*	1.029E-09	**
sig.diff (%)	**62.5%**	**71.4%**	0.0%	33.3%	8.3%	**66.7%**	**58.3%**		

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

In this analysis, we conducted a chi-square test between possible error counts from all card combinations and actual error counts made by students for each error type in Level 5 assignments. The result is shown in Table 2. We found significant difference ($p<.05$) in ten out of twelve assignments, which shows that students had an inclination to choose different card combinations than what has been predicted in possible error counts. If the students posed problems randomly, the distribution would not have a significant difference than the prediction in possible error counts. Therefore, this finding strengthens our hypothesis that students did not pose problems randomly, but with some sort of thinking. Furthermore, we observed that among the error types, students had the tendency to made mistakes in story type (error type 1), calculation (type 2), objects and numbers (type 6), and failed to build a correct problem structure (type 7), which shown by high percentage of significant difference (sig.diff >50%) found in the respective error types.

3.3 Meaningful Errors according to the Triplet Structure Model

We have explained in Section 2.3 that according to the task model of problem posing which are derived from the principle in the Triplet Structure Model, there are five constraints to be satisfied to form a correct problem. In this analysis, we conducted a chi-square test between possible count of satisfied constraints from all card combinations and actual count of satisfied constraints in students' posed problems in Level 5 assignments.

First, we investigated the number of satisfied constraints by all possible card combinations in each assignment. Naturally, the number of card combinations decreases as the number of satisfied constraints increase. In total, there are only 9% of all combinations that does not satisfy any constraint, thus we call them meaningless errors. 48% of the card combinations satisfy only 1 constraint, and 32% of them satisfy 2 constraints. The percentage of card combinations that satisfy 3 and 4 constraints are 1% and 5%, respectively, while the rest of 4% satisfy 5 constraints, which are the correct answers. From the percentages, we could see that the majority of the card combinations only satisfy 1 or 2 constraints.

Next, we focus to investigate satisfied constraints by students' first attempt of posing problem in each assignment, which is the first combination of three sentence cards that they selected to be assessed by Monsakun software. The result of correlation analysis is shown in Table 3. We found significant difference in all assignments ($p<.05$), which shows that students made a conscious attempt to satisfy at least one constraint in any given assignments.

Table 3. Correlation Analysis between Possible and Actual Satisfied Constraints in First Attempt of Posing Problem in Level 5 Assignments

Assignment	**Number of Satisfied Constraints**						**Possible vs Actual**	
	0	**1**	**2**	**3**	**4**	**5**	**Chi-Sq**	**p**
1	L n.s..	L n.s..	M n.s.		M **	L n.s.	< 0.01	**
2	L **	L **	L +		M n.s.	M **	< 0.01	**
3	L +	L *	L *		L n.s.	M **	< 0.01	**
4		L **	L n.s.		M **	L n.s.	< 0.01	**
5		L **	L n.s.		M **	M **	< 0.01	**
6		L **	L n.s.	M **	M *	M n.s.	< 0.01	**
7		L *	L **	M *	M **	M n.s.	< 0.01	**
8		L **	L n.s.		M n.s.	M **	< 0.01	**
9		L **	M n.s.	L n.s..	M *	M **	< 0.01	**
10	M n.s.	L *	L n.s.		M n.s.	M +	0.043	*
11	L +	L **	L n.s.		M **	M **	< 0.01	**
12	L +	L *	L n.s.		M **	M **	< 0.01	**
sig.diff (%)	16.7%	**91.7%**	16.7%	**66.7%**	**66.7%**	**58.3%**		

L: Percentage of actual number is lower than the possible number, M: Percentage of actual number is more than the possible number
**: significant difference ($p<.01$), *: significant difference ($p<.05$), +:, marginal difference ($p<.1$)

In addition, we pay attention to the percentage of actual number compared to possible number of card combinations. Here, possible number means the number of card combination that is possibly made by the students. This number is constructed based on the characteristic of correct cards and dummy cards provided in each assignment. Actual number means the number of card combination that is actually made by the students, that is, students' answers. We found that the actual number of answers satisfying less than three constraints is lower than the possible number, while the actual number satisfying more than three constraints is higher than the possible number.This implies students were trying to satisfy as many constraints as possible when they constructed their answer.

In assignments 4 – 9, because of the design of the sentence cards, there is at least one constraint satisfied by default. Despite this fact, the result of chi-squared test still shows significant difference for these assignments. Moreover, the rate of 3 and 4 satisfied constraints has a high percentage (sig.diff >50%), showing that despite the initial possible prediction of low percentage in 3 or 4 satisfied constraints, they were able to select card combinations which satisfy these constraints.

This finding shows that most of the students were successful in understanding the given requirements in an assignment, translating them into the necessary constraints, and choosing the sentence cards that satisfies the constraints. Thus, we justify that students' posed problems conforms the Triplet Structure Model that stated the structure requirements to build arithmetic word problems.

From students' posed problems, we selected frequent error combinations (>10%) and investigated the satisfied constraints in different story types. Because these combinations are incorrect answers, they automatically fulfill only four out of five constraints, whose percentages are shown in Figure 8. The result show that 96.3% of the frequent incorrect answers satisfy the object constraint, and 85.2% of them satisfy the number constraint. It means that the first grade of elementary school students were able to perceive the correct objects and numbers needed to pose a correct problem. However, they faced difficulties in relating the numbers with the requirement of story type and calculation, which shows lower satisfied percentage of 40.7% and 33.3%, respectively.

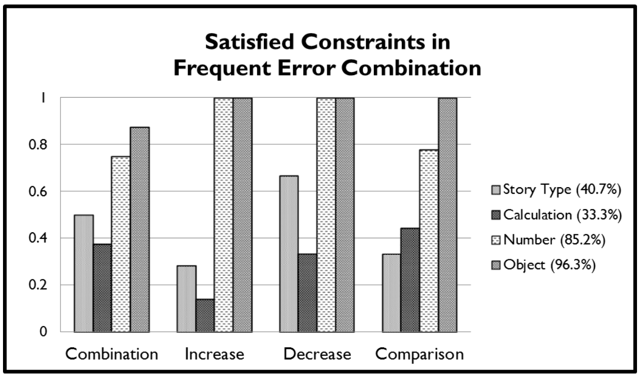

Figure 8. Satisfied constraints in frequent error combination

4. Concluding Remarks

In this research, we have conducted analysis of Monsakun log data of elementary school students' problem posing activity to investigate their way of thinking in posing different type of arithmetical word problems. The analysis shows that students using Monsakun did not pose problems randomly, but with some sort of thinking process. Furthermore, we show that the frequent error combination made by the students contains meaningful errors, according to the Triplet Structure Model, that students actually think to satisfy as many constraints as possible in order to pose a correct problem in a given assignment. The process of understanding assignment requirement and relating them to suitable sentence cards is an important point especially for young learners to reach deep understanding of the structure of arithmetic word problems.

For future research, we plan to analyze more data of Monsakun use in various elementary schools to strengthen our justification of the Triplet Structure Model. Furthermore, similar thinking process analysis would be investigated in the implementation of Monsakun in foreign languages, to show the independency of our model from the initial language (Japanese).

Acknowledgements

This work was supported by JSPS KAKENHI Grant Number 15H02931.

References

Ellerton, N.F. (1986). Children's Made Up Mathematics Problems: A New Perspective on Talented Mathematicians. *Educational Studies in Mathematics*, Vol.17, 261-271.

English, L. D. (2003). Problem posing in elementary curriculum. In F. Lester & R. Charles (Eds.), *Teaching Mathematics through Problem Solving*. Reston, Virginia: National Council of Teachers of Mathematics.

Hasanah, N., Hirashima, T., Hayashi, Y. (2014a). Analysis of Students' Thinking Process in a Problem-Posing Environment of Arithmetical Word Problems. *Proceedings of JSAI2014.*

Hasanah, N., Hirashima, T., Hayashi, Y. (2014b). Revealing Students' Thinking Process in Problem-Posing Exercises: Analysis of First Sentence Selection. *Proceedings of ICCE2014.*

Hirashima, T., Yokoyama, T., Okamoto, M., & Takeuchi, A. (2007). Learning by Problem-Posing as Sentence-Integration and Experimental Use. *Proceedings of AIED2007*, 254-261.

Hirashima, T. & Kurayama, M. (2011). Learning by Problem-Posing for Reverse-Thinking Problems, *Proceedings of AIED2011*, 123-130.

Hirashima, T., Yokoyama, T., Okamoto, M., & Takeuchi, A. (2008). Long-term use of learning environment for problem-posing in arithmetical word problems. *Proceedings of ICCE2008*, 817-824.

Hirashima, T., Yamamoto, M., Hayashi, Y.. (2014). Triplet Structure Model of Arithmetical Word Problems for Learning by Problem-Posing. *Proceedings of HCII2014*, pp42-50.

Kurayama, M., & Hirashima, T. (2010). Interactive Learning Environment Designed Based on Task Model of Problem-Posing. *Proceedings of ICCE2010*.

Polya, G. (1957). How to solve it: A new aspect of mathematical method. Princeton University Press.

Riley, M.S., Greeno, J.G., & Heller J.I. (1983). Development of Children's Problem-Solving Ability in Arithmetic. The Development of Mathematical Thinking, Ginsburg H. (ed.), Academic Press, 153-196.

Silver, E.A. & Cai, J. (1996). An Analysis of Arithmetic Problem Posing by Middle School Students. *Journal of Research in Mathematics Education*, vol.27, No.5, 521-539.

Yamamoto, S., Kanbe, T., Yoshida, Y., Maeda, K., & Hirashima, T. (2013). Learning by Problem-Posing with Online Connected Media Tablets. *Proceedings of HIMI/HCII 2013*, Part III, 165-174.