Doctoral Thesis

Thinking Process Analysis and Multiple-Languages Utilization in a Learning Environment for Problem Posing as Sentence Integration

(単文統合型作問の学習環境における
思考過程分析と複数言語での活用)

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ABSTRACT

Arithmetic word problems remain one of the most difficult areas of teaching mathematics. Young students who have mastered simple additions and subtractions often stumbled when facing word problems which require understanding of the conceptual knowledge. Problem posing practice involves the generation of new problems in addition to solving pre-formulated problems. However, achieving practical implementation of learning by problem posing faces the issue of inefficiency due to the time needed for assessment and giving feedback to students' posed problems. To address this issue, several researchers have attempted to build an Intelligent Learning System to automate the problem posing assessment and incorporate the system in school practice. The effectiveness of problem posing method has been investigated for a variety range of learners.

Monsakun (means "Problem-posing Boy" in Japanese) is a computer-based learning environment to realize learning by problem-posing in a practical way for one operation of addition and subtraction. In the previous studies, the acceptance of Japanese children towards Monsakun have been analyzed in the practical study in the classroom using pre and posttest to evaluate the learning outcome. However, the learning process has not been analyzed yet. The system is designed to promote learners to think about constraints when posing problems. It is necessary to observe whether learners' activity in posing problem follow our design, which in turn elucidates the learning effect of Monsakun. We hypothesized that the choice learners made in the problem posing activity would be able to explain whether Monsakun encourages learners to think about the structure of arithmetic word problems. Accordingly, the first aim of this study is to investigate the learning process through the result of problem posing activity.

The integration process of solving arithmetic word problem involves processing the linguistic meaning into arithmetical formulas which are similar in any language. Based on these, the expected role of Triplet-structure model is to describe the quantitative

information to bridge the gap between the linguistic and the numeric information. Although the meaning of numbers is not represented in the numeric information expressed as equation, it is necessary to ensure the consistency between the linguistic and the numeric information. The second aim of this study is to utilize the Triplet-structure model in multiple languages as an initial research towards suggesting a universal sentence-integration method to learn problem-posing in arithmetical word problems.

This thesis consists of seven chapters. In **Chapter 1**, the research context and motivation are described, following by research questions, research goals, and the general structure of the thesis. **Chapter 2** outlines the activity of learning by problem-posing, the Triplet Structure Model and the task model of problem-posing, following with the introduction on Monsakun as learning environment for problem posing. In **Chapter 3**, we conducted analysis from the log data of university students using Monsakun to understand students' thinking process in problem posing. In the first step of analysis, we focused on the first sentence card selected in the process of posing a problem. We investigated whether learner's selection changed through the different level of exercise. The analysis of university students' log data served as a preliminary study towards the next chapter. In **Chapter 4**, we investigated problems posed by elementary school students in Monsakun to understand whether Monsakun encourages them to think about the structure of arithmetic word problems. The study was conducted by testing the randomness of learners' answers and analyzes the trend of them. We also investigated the frequent errors and the satisfied constraints from students' answers. In **Chapter 5**, we investigated whether Triplet Structure Model depends on Japanese language. We analyzed the use of Monsakun in English or Indonesian by non-native Japanese adults and compared it with the use of Japanese children and adults. Furthermore, we investigated the satisfied constraints and the acceptance of Monsakun through a questionnaire for the foreign students. As a follow-up of the previous research, **Chapter 6** reported the experimental use of Monsakun for Indonesian elementary school students living in Japan. We introduced them to problem-posing through sentence-integration based on the Triplet-structure model and analyzed their learning activities using Monsakun. This research is a pre-step towards the practical use for elementary school children in other countries. Finally, in **Chapter 7** we revisits the studies presented in this thesis and suggests promising future studies.

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Author

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LIST OF PUBLICATIONS

Publications

Journal Articles

RPTEL 2017: Hasanah, N., Hayashi, Y., & Hirashima, T. (2017a). An analysis of learner outputs in problem posing as sentence-integration in arithmetic word problems. *Research and Practice in Technology Enhanced Learning (RPTEL)*, 12:9. (DOI: 10.1186/s41039-017-0049-5)

JISE 2019: Hasanah, N., Hayashi, Y., & Hirashima, T. (2019). Utilization Analysis of Posing Arithmetic Word Problem as Sentence-Integration Learning Environment in Multiple Languages. *Japanese Society for Information and Systems in Education (JISE)*, article in press.

International Conference Papers

ICSLE 2014: Hasanah, N., Hayashi, Y., & Hirashima, T. (2014a). Analysis of Problem-Posing Process of Arithmetical Word Problem as Sentence Integration: Viewpoint of First Selected Sentence. *International Conference on Smart Learning Environments, Hong Kong Institute of Education (HKIEd 2014)*, Hong Kong, China.

ICCE 2014: Hasanah, N., Hayashi, Y., & Hirashima, T. (2014b). Revealing Students' Thinking Process in Problem-Posing Exercises: Analysis of First Sentence Selection. *The 22th International Conference on Computers in Education (ICCE 2014),* Nara, Japan.

ICCE 2015: Hasanah, N., Hayashi, Y., & Hirashima, T. (2015a). Investigation of Students' Performance in Monsakun Problem Posing Activity based on the Triplet Structure Model of Arithmetical Word Problems. *The 23rd International Conference on Computers in Education (ICCE 2015),* Hangzhou, China.

MSCEIS 2016: Hasanah, N, Hayashi, Y, & Hirashima, T. (2016). Investigation of Learning Environment for Arithmetic Word Problems by Problem Posing as Sentence Integration in Indonesian Language. *The 3rd Mathematics, Science and Computer Science Education International Seminar (MSCEIS 2016),* Bandung, Indonesia.

Local Conference Papers

JSAI 2014: Hasanah, N., Hayashi, Y., & Hirashima, T. (2014c). Analysis of Students' Thinking Process in a Problem-Posing Environment of Arithmetical Word Problems Sentence. *The 28th Annual Conference of the Japan Society of Artificial Intelligence (JSAI 2014),* Ehime, Japan.

SIG-ALST 2014: Hasanah, N., Hayashi, Y., & Hirashima, T. (2015b). Utilization Analysis of Monsakun in Multiple Languages as Validation of Triplet Structure Model of Arithmetical Word Problems. *The 69th SIG on Advanced Learning Science and Technology (SIG-ALST 2014),* Kanagawa, Japan.

Book Chapters

EISL 2014: Hasanah, N., Hayashi, Y., & Hirashima, T. (2014d). Analysis of Problem-Posing Process of Arithmetical Word Problem as Sentence Integration: Viewpoint of First Selected Sentence. *Lecture Notes in Educational Technology: Emerging Issues in Smart Learning*, Chapter 11, pp 85-88. (DOI: 10.1007/978-3-662-44188-6_11)

JPCS 2017: Hasanah, N, Hayashi, Y, & Hirashima, T. (2017b). Investigation of learning environment for arithmetic word problems by problem posing as sentence integration in Indonesian language. *Journal of Physics Conference Series* 812(1):012060. (DOI:10.1088/1742-6596/812/1/012060)

Source and Original Work

Original material of my own from the above publications has been included in this thesis, with a citation to the appropriate publication appearing at the beginning of each chapter. Other external sources are cited, with the bibliography appearing at the end of the thesis.

Use of Work by Others

The dataset of Japanese first-grade elementary school students that are analyzed in some parts of this thesis was collected through a study conducted by a fellow researcher, Yamamoto et al. (2012). However, the analysis of these data is part of the original contributions of studies in this thesis.

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CHAPTER 1

INTRODUCTION

Summary: This chapter describes the research context and motivation, following by related researches, research questions, research goals, and the general structure of the thesis. The first aim of this thesis is to analyze the posed problems by university students as well as elementary school students on Monsakun in terms of whether Monsakun encourages learners to think about the structure of arithmetic word problems. The second aim of this thesis is to investigate whether Triplet Structure Model can work with languages other than Japanese and to conduct an experimental use of Monsakun in Indonesian language to discover their acceptance towards the learning environment for problem-posing.

1.1 Context and Motivation

Two activities that have been identified to be central themes in mathematics education are problem posing and problem solving. Problem solving practice, as the most popular way of teaching the solution method, has been long integrated into school mathematics (Stanic & Kilpatrick, 1988). Problem posing practice involves the generation of new problems in addition to solving pre-formulated problems (English, 1997; Silver & Cai, 1996). Although learning by problem posing has been suggested as an important way to promote learner's understanding (Ellerton, 1986; Polya, 1957), it was not until recently that the recommendations for the reform in mathematics education suggested the problem posing inclusion in students' activities (NCTM, 2000). Several investigations of various aspects of problem posing activities have been conducted as more educators and researchers realized its importance in math education (English, 1998; English, 2003).

Arithmetic word problems remain one of the most difficult areas of teaching mathematics. Young students who have mastered simple additions and subtractions often stumbled when facing word problems which require understanding of the conceptual knowledge (Riley, Greeno, & Heller, 1983). Tasking students with the generation of a new arithmetic problem and construction of a new numerical relation can be seen as an effort towards better understanding of word problems (Brown & Walter, 1990). However, achieving practical implementation of learning by problem posing faces the issue of inefficiency due to the 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 (Nakano et al, 1999).

In Indonesia, not unlike the rest of the world, arithmetic word problems also remain one of the most difficult area of teaching mathematics. Indonesian Mathematics Teaching Monitoring and Evaluation result (P4TK ME) showed more than 50% teachers reported that most students have difficulty in solving word problems, due to not having a clear picture regarding the link between contextual daily state with the corresponding mathematical sentence, and not actively utilizing their mental state in problem solving (Raharjo, 2008). There are abundant room for improvements in Mathematics classroom in Indonesia to encourage more creative thinking and active involvement from students. Math teachers usually conduct a classroom by explaining the learning material in detail, such as providing formulas and examples of problems. Example problems are largely solved by teachers themselves and the students simply imitate the way to solve problems just like what the teacher did. A survey of 130 primary school teachers in Indonesia showed that 56.1% of them never ask students to create their own questions (Siswono et al., 2008). Interview with 27 middle school teachers disclosed that they believed the mathematical procedure needed to solve a problem should be given explicitly (Wijaya, 2015), which leave no room for creative thinking.

Investigation of math textbooks in Indonesia regarding word problems showed a lot of room for improvements as well. A survey of Indonesian textbooks (grade 3 to 6) in 2000 found the alarming decrease of problem solving items down to less than 500, compared to over 2500 in the early 1960's; and in the present problems, the providing of clue words is presently at an all-time high (Harta, 2000). Another survey of math textbooks in grade 8 discovered only 10% of tasks could be labeled as context-based tasks which relates math to real world problems, and most of them provided just precisely the information needed to solve a task, which signifies a lack of opportunities for students to learn to select relevant information to solve word problems (Wijaya, 2015).

The benefit of students' active involvement in math classroom is discussed in Schifter et al (2009). Lessons organized for bringing students' attention and discussion about operational behaviour evokes students' understanding and support their computational fluency. They found that developing students' early algebraic thinking benefits their learning representations, connections, and generalizations in the elementary school grades.

Another crucial ability for students required in real life is the ability to gather information, analyze them, and pick only the necessary ones to solve problem. Therefore, problems containing irrelevant information, called extraneous problems, should be used in textbooks and classroom for students to gain these skills (Muth, 1992). Extraneous problems contain more than information or situations required to solve the problem. Muth encourages teachers to include extraneous information in word problems on a regular basis and to train students to be aware of the possibility that extraneous information may be present. Muth believes this will help preparing students to deal with real world math problems they will experience outside school. However, in Indonesia, students do not frequently experience with these kinds of problems. For example, when the researcher examined textbooks used in 1^{st}-3^{rd} grade of elementary school, this kind of problem is not seen. Presently, no research was found regarding word problems with extraneous information in Indonesia.

In Indonesia, practice of problem posing was introduced in National Conferences and Journal of Education (Suryanto, 1998; As'ari, 2000) to improve the professionalism of mathematics teachers in conducting classroom. The application of new Competence-Based Curriculum (CBC/KBK) in Indonesia in 2004 then started new teaching method called Indonesian Realistic Mathematics Education (IRME/PRMI), in which problem posing method is encouraged as a means to improve students' problem development and problem solving ability (Suharta, 2003). Since then, various researches in problem posing practice has been conducted in Indonesia, reporting increased motivation and active performance in classroom (Sumarni, 2008) and learning completeness percentage (Mubarotin, 2011). However, reports of students inaccustomed to problem posing task facing difficulty to carry out the learning and teacher needed extra time to evaluate the posed problems were observed (Siswono, 2004).

Researches have shown that problem posing activities positively influences students' ability to solve mathematical problems and provide an opportunity to look deeper into students' understanding of mathematical concepts and processes (Christou et al., 2005; English, 2003). Researches of problem posing in Indonesia have reported students' increased creativity, where they were able to create their own problem using new information or change from present problem (Widana, 2013). Students had increased motivation and active performance in classroom (Sumarni, 2008) and learning completeness percentage (Mubarotin, 2011). There was significant difference between learning result from students using problem posing method and conventional method (Sari, 2013). In a study of 40 elementary teachers implementing problem solving – posing based learning model, students became active learners by creating and challenging problems (Siswono, 2015).

However, there are some drawbacks in problem posing implementation in common classroom situation. Students with lower comprehension in math and language concept needed teachers' assistance to create problems (Sumarni, 2008; Widana, 2013). Students inaccustomed to problem posing task faced difficulty to carry out the learning (Siswono, 2004). More time was needed to conduct group discussion to solve the posed problem swapped from other group, and some students felt awkward working in a group with other students s/he did not like (Widana, 2013). Teachers also needed longer preparation time and implementation time, and assessment process needs specific skills to conduct (Siswono, 2015).

During the process of solving arithmetic word problems, learners go through four processes: translation, integration, planning, and execution (Mayer, 1999). The process of translation and integration are called problem comprehension process, and the rests are problem execution process. In other words, learners need to be able to comprehend the problem before they execute it. Learning by problem-posing is a way to teach students to promote understanding of word problem. However, students generally pose limited but diverse problems, and teachers need more time to assess and give feedback to students' posed problems (Nakano, 1999).

Monsakun (means "Problem-posing Boy" in Japanese) is a computer-based learning environment to realize learning by problem-posing in a practical way for one operation of addition and subtraction. The software delivers the process of assessment and giving feedback to students' posed problems automatically, enabling teachers to monitor students' progress individually as well as all students in a classroom in a real time (Hirashima et al., 2007; Kurayama & Hirashima, 2010). In Monsakun, 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 using the numerical expression by selecting and arranging appropriate cards. 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 essentially the same as ordinary problem-posing activity. Hirashima & Kurayama (2011) call this style as "problem-posing as sentence-integration" and assert that this integration process is an essential activity in learning.

In this study, we present a learning environment for posing arithmetic word problem, which require students to create problems instead of solving it, and to distinguish between necessary and extraneous information in the process of creating problem. Our problem posing learning environment address the issue of assessment and feedback time faced by the teachers by automatic agent-assessment method. The issue of math and language concept comprehension faced by some students is addressed by providing a closed problem space using simple sentence cards, which students can easily select and arrange to create a problem. The closed problem space also enable the recording and analysis of students' log data, which can give insight to their comprehension of arithmetic concepts and processes. By providing a learning environment that encourage students' active involvement and the use of extraneous problems, it is hoped that students could gain creative thinking ability in mathematics.

Researches of problem posing environments generally reported effectiveness of the problem posing practice using pretest and posttest comparisons to evaluate the learning outcome. However, it is necessary to further analyze the learning process using the data collected by the system to get better view of learner's problem posing process in order to capture learner's understanding of math and science concepts (Birch & Beal, 2008). The first aim of this study is to investigate the learner products in problem posing, that is, posed problems. We argue that problem posing is an activity that promotes learners to think structurally about arithmetic word problems. Accordingly, our system is designed to promote learners to think about constraints when posing problems. It is necessary to observe whether learners' activity in posing problem follow our design, which in turn elucidates the learning effect of Monsakun. By analysis of the products we evaluate that "learners have thought about the structure of problems" and "learners' thinking about the structure has been improved in accordance with the progress of exercise".

The integration process of solving arithmetic word problem involves processing the linguistic meaning into arithmetical formulas which are similar in any language (Mayer, 1999). A study about the role of language and visuospatial representation in mathematical thinking shows that the exact arithmetic knowledge is stored in a language-specific format, while the quantity manipulation is done using a language-independent representation of number magnitude in visuospatial processing (Dehaene et al., 1999). Based on the study, the expected role of Triplet-structure model is to describe the quantitative information to bridge the gap between the linguistic and the numeric information. The quantitative information consists of numbers with the meaning derived from the linguistic information represented as sentences of a story. Although the meaning of numbers is not represented in the numeric information expressed as equation, it is necessary to ensure the consistency between the linguistic and the numeric information. In this sense, Triplet-structure model must have a relationship with languages. If the relationship depends on Japanese, the model has a disadvantage for arithmetic word problems in any other languages than Japanese. The second aim of this study is to utilize the Triplet-structure model in multiple languages as an initial research towards suggesting a universal learning environment to learn problem-posing by sentence-integration.

1.2 Related Researches: Software-based Problem Posing

To address the issue of limited number of posed problem by the students and limited time for teachers to assess them, several researchers have attempted to build an Intelligent Learning System to automate the problem posing assessment and incorporate the system in school practice. The distinction between them is shown in Figure 1-1. AnimalWatch is a web-based learning environment that enables teachers and students to create and share arithmetic word problems in fifth grade elementary school (Arroyo, Schapira & Woolf, 2001; Arroyo & Woolf, 2003). This study was carried further for middle school students with the subject of arithmetic and fractions (Beal, et al, 2010; Birch & Beal, 2008). The system successfully changed students' role from consumers to producers of Intelligent Tutoring System contents.

Another study was conducted where a learning environment systematically presented examples of problems to undergraduate students, and afterwards they are asked to build a variety of problems based on the example (Kojima & Miwa, 2008; Kojima, Miwa & Matsui, 2010). The system supported mathematical problem posing through examples and it increase the diversification of problem contents, thus enabling students to learn more through the problem-posing activity.

Most research on problem posing was conducted on higher grade of school, as we have seen in undergraduate students by Kojima & Miwa (2008) and in high school students (Van Harpen & Sriraman, 2013). Furthermore, research findings on middle school students were also reported in several papers (Birch & Beal, 2008; Silver & Cai, 1996; Walkington & Bernacki, 2015). For elementary school students, the AnimalWatch by Arroyo & Woolf (2003) targeted fifth grade students. Hirashima et al (2008) targeted elementary school students in their research using Monsakun as an interactive problem posing learning environment, mainly the second grade students for simple addition and subtraction.

The development of Monsakun was started by Nakano et al. (1999) who proposed a sentence template method for arithmetic word problem, followed by the problem template method (Hirashima et al., 2000; Nakano et al., 2002). The sentence card method was introduced in (Hirashima et al., 2007), which then implemented in Monsakun. The task model of problem posing was proposed by Kurayama and Hirashima (2010). Reverse-thinking problem was investigated by Hirashima and Kurayama (2011). Yamamoto et al (2013) conducted a research in which they implemented Monsakun in online connected media tablets which was used in elementary school classroom over the course of a few months. The triplet structure model was proposed by Hirashima et al (2014). As a continuation of the research, this study analyzed learners' thinking process and the multiple-language utilization of Monsakun. Figure 1-2 illustrates the flow of Monsakun research at a glance.

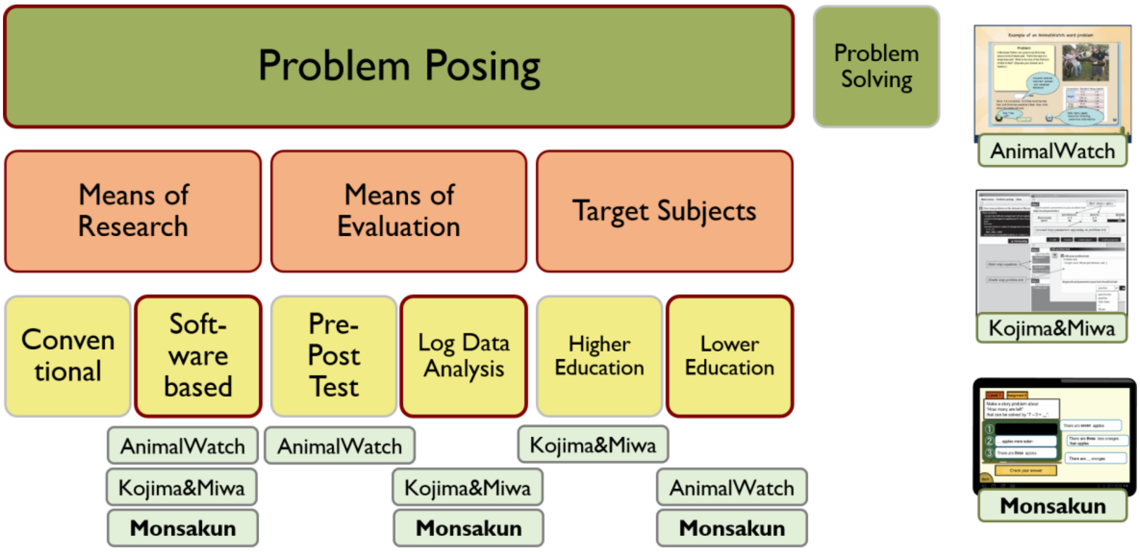


Figure 1-1 Related researches: categorization of several Intelligent Tutoring Systems

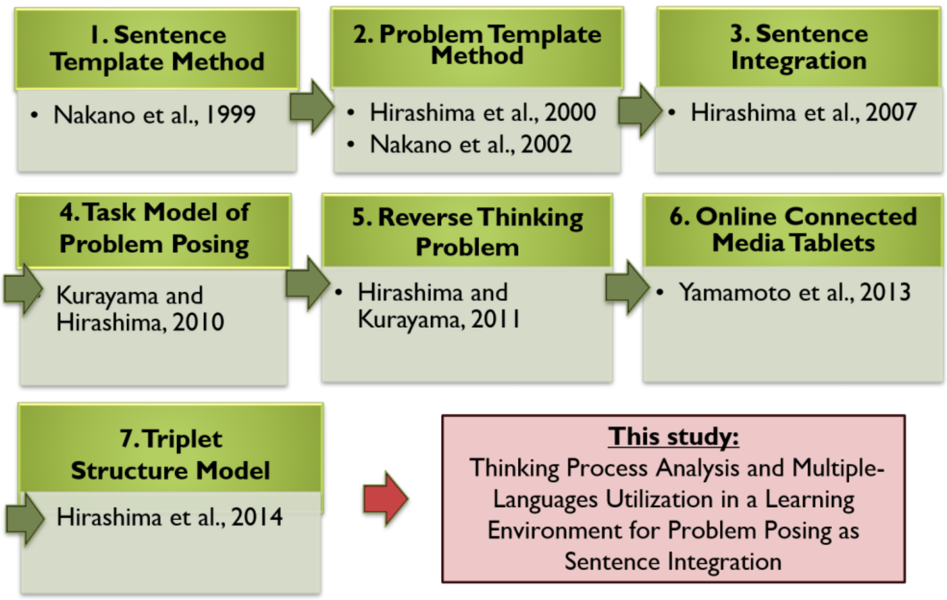


Figure 1-2 Research and development of Monsakun

1.3 Research Questions

Even though students seem to be highly engrossed in learning activities using computer or tablet, Dynarski et al (2007) shows not much evidence of the software influence on higher performance of math and reading in the students. Conducting pre and posttest are the most common way to evaluate a learning environment as seen in Beal et al (2010), Chang et al (2012), and Oliveira et al (2015). Another way is to conduct a deep analysis of the students' behavior as seen in Biswas et al. (2005 and 2010). The effectiveness of Monsakun in practical use has been reported in previous studies using pre and posttest evaluation (Yamamoto et al, 2012). In this sense, previous researches had analyzed the learning outcome, however the learning process has not been investigated thoroughly yet. Supianto et al. (2016) had started a study of the learning process through the log of interaction data. In the first part of this study (Chapter 3 and 4), we report on our analysis of the learning process by university students as well as elementary school students on Monsakun in terms of whether Monsakun encourages learners to think about the structure of arithmetic word problems.

In the previous studies, Japanese children accept Monsakun in the practical study in the classroom (Yamamoto et al., 2012). The analysis of the use of Monsakun by Japanese elementary school students and university students shows that the trends of correctness rate among levels in Monsakun are similar between children and adults (Hasanah et al., 2015b). In the second part of this study (Chapter 5 and 6), we investigated whether Triplet Structure Model can work with languages other than Japanese. We compare the use of Monsakun in Japanese and ones in English and Indonesian to check the dependency of the relationship between the model and the linguistic information on a particular languages. If non-native Japanese adults can pose problems in Monsakun as well as Japanese adults, as Japanese children have learned the nature of arithmetic word problems and have posed problems in the same manners as Japanese adults, it is hoped that Monsakun can contribute to English and Indonesian children's learning of arithmetic word problems as well. Furthermore, we conducted an experimental use of Monsakun in Indonesian language for a number of Indonesian elementary school children and analyzed the log data to discover their acceptance towards the learning environment.

Based on the elaborated context, we formulated the research questions as follows:

[RQ-1] Do learners pose problems in Monsakun with a consideration towards the sentence structure?

[RQ-2] In what way the trends of posed problems by learners could be explained with the Triplet Structure Model?

[RQ-3] How does Japanese adult pose problems in Monsakun compare to Japanese elementary school children?

[RQ-4] Is Monsakun in languages other than Japanese acceptable to non-native Japanese speakers?

1.4 Research Goals

With consideration of the research context and research questions, we have defined the main goals of this research as follows:

1. *Investigate learners' thinking process through the result of problem-posing activity, that is, the posed problems.*

As a study of learning effect, the previous works addressed the acceptance of Monsakun through practical use in the classroom for elementary school students (Yamamoto et al, 2012). However, the analysis of the posed problems were limited in examining the type of errors and the number of posed problems which were then compared to a traditional problem-posing approach to show the usefulness of the learning environment system that we have built. Our system is designed to promote learners to think about constraints when posing problems. An investigation of the learning process is necessary to observe whether learners' activity in posing problem follow our design, which in turn elucidates the learning effect of Monsakun. Therefore, we conducted an analysis of the learning process by focusing on the posed problems as the product of learning problem posing with Monsakun.

We investigated the first selected sentence and analyzing a selected path of learners' answers to address our first question **[RQ-1]**: "Do learners pose problems in Monsakun with a consideration towards the sentence structure?", which are described in Chapter 3 and in the following publications (Hasanah et al, 2014a; Hasanah et al, 2014b; Hasanah et al, 2014c; Hasanah et al, 2014d).

Furthermore, we analyzed the satisfied constraints of the actual posed problems compared to the system setting to address our second question **[RQ-2]**: "In what way the trends of posed problems by learners could be explained with the Triplet Structure

Model?". This research is explained in Chapter 4, and the associated results were published in the following papers (Hasanah et al., 2015a; Hasanah et al., 2017a).

2. *Conduct and analyze the utilization of Monsakun in multiple languages in order to validate the language independency of Triplet Structure Model.*

To address the third question **[RQ-3]**: "How does Japanese adult pose problems in Monsakun compared to Japanese elementary school children?", we analyzed the posed problems by Japanese university students and compared them with Japanese elementary school students. The research is described in Chapter 5 and published in the following paper (Hasanah et al., 2015b; Hasanah et al., 2019).

The experimental use of Monsakun in English and Indonesian is necessary to investigate the dependency of the relationship between Triplet structure-model and the linguistic information on a particular language. This goal addresses the fourth question **[RQ-4]**: "Is Monsakun in languages other than Japanese acceptable to non-native Japanese speakers?" The research is explained in Chapter 5 and Chapter 6 and published in the following papers (Hasanah et al., 2016; Hasanah et al., 2017b; Hasanah et al., 2019). Through this study, it is hoped that Monsakun can contribute to English and Indonesian children's learning of arithmetic word problems as well.

1.5 Thesis Structure

This section describes the chapters of the thesis. The structure of the thesis and the publications associated with each chapter is illustrated in Figure 1-3.

Chapter 1: *Introduction*

This chapter describes the research context and motivation, following by research questions, research goals, and the general structure of the thesis.

Chapter 2: *Background*

This chapter outlines the activity of learning by problem-posing, the problem categorization and types of problem thinking. The Triplet Structure Model and the task model of problem-posing were described, following with the introduction on Monsakun as learning environment for problem posing. The graph of learner's card selection was explained to show the problem space.

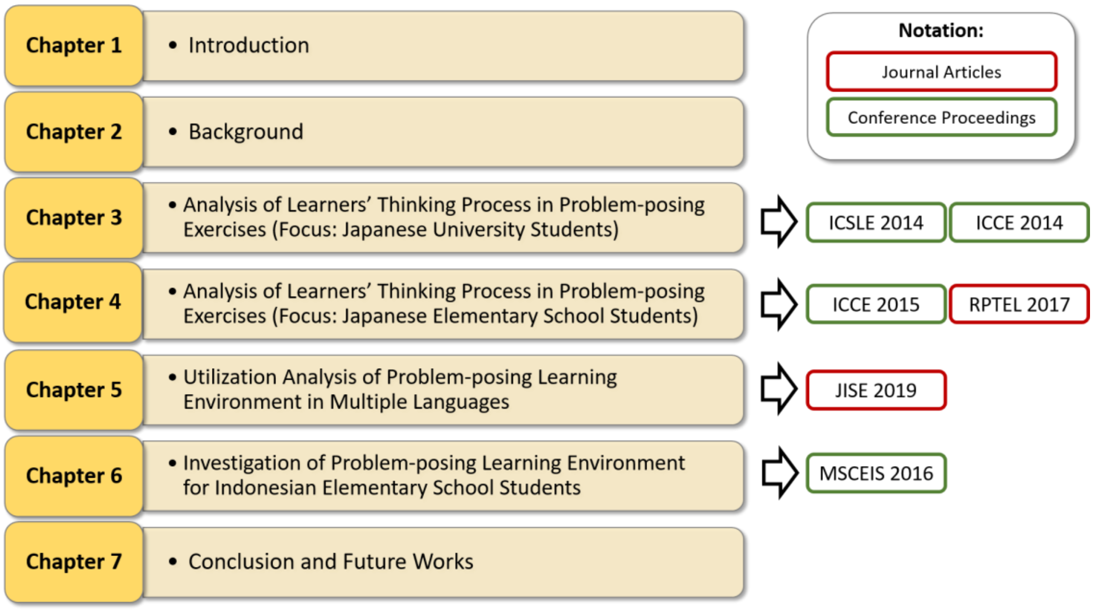


Figure 1-3 Structure of the thesis and related publications

Chapter 3: *Analysis of Learners' Thinking Process In Problem-posing Exercises (Focus: Japanese University Students)*

In this chapter, we conducted analysis from the log data of university students using Monsakun to understand students' thinking process while posing arithmetical word problems. Eleven university students were participated in the experiment. In the first step of analysis, we focused on the first sentence card selected in the process of posing a problem. We investigated whether learner's selection changed through the different level of exercise. We also consider commonly occurred mistakes and students' thinking process from frequent paths taken by students in one of the problem. The analysis of university students' log data served as a preliminary study towards the next chapter.

Chapter 4: *Analysis of Learners' Thinking Process In Problem-posing Exercises (Focus: Japanese Elementary School Students)*

In this chapter, we investigated problems posed by elementary school students in Monsakun to understand whether Monsakun encourages them to think about the structure of arithmetic word problems. The study was conducted by testing the randomness of learners' answers and analyzes the trend of them. We also investigated the frequent errors and the satisfied constraints from students' answers.

Chapter 5: *Utilization Analysis of Problem-posing Learning Environment in Multiple Languages*

In this chapter, we investigated whether Triplet Structure Model depends on Japanese language. We analyzed the use of Monsakun in English or Indonesian by non-native Japanese adults and compared it with the use of Japanese children and adults. Furthermore, we investigated the satisfied constraints and the acceptance of Monsakun through a questionnaire for the foreign students.

Chapter 6: *Investigation of Problem-posing Learning Environment for Indonesian Elementary School Students*

Previous studies has reported the use of Monsakun learning environment for problem-posing in actual Japanese elementary school classrooms and its effectiveness has been confirmed. As a follow-up of the previous research, in this study, ten Indonesian elementary school students living in Japan participated in a learning session of problem posing using Monsakun in Indonesian language. We introduced them to problem-posing through sentence-integration based on the Triplet-structure model and analyzed their learning activities using Monsakun. The result is presented in this chapter.

Chapter 7: *Conclusion and Future Works*

This chapter revisits the studies presented in this thesis and suggests promising future studies.

CHAPTER 2

BACKGROUND

Summary: This chapter outlines the activity of learning by problem-posing, the problem categorization and types of problem thinking. The Triplet Structure Model and the task model of problem-posing were described, following with the introduction on Monsakun as learning environment for problem posing. Finally, the graph of learner's card selection was explained to show the problem space in Monsakun.

2.1 Learning by Problem Posing

Learning by problem posing has been suggested as an important way to promote learner 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 (English, 1997; Silver & Cai, 1996). It is one of the important foundations of reformation in mathematics education, and the realization of its importance has led into growing research of various aspects in activities of learning by problem posing (English, 1998; English, 2003; NCTM, 2000).

2.1.1 Categorization of Problem-posing Exercises

In arithmetical word problems, sentences are divided into two types: independent quantity sentence and relative quantity sentence. A relative quantity sentence contains keyword determining the type of story, for example, "…eaten", "…in total", "…less than…" or "…more than…". An arithmetic word problem of binary operation is integration of two independent quantity sentences and one relative quantity 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 decrease story type problem is composed as follows:

a) There are seven apples *(independent quantity sentence)*,

b) Several apples were eaten *(relative quantity sentence: decrease story type)*, and

c) There are three apples *(independent quantity sentence)*.

On the other hand, a combination story type problem consists of the followings:

a) There are seven apples *(independent quantity sentence)*,

b) There are three oranges *(independent quantity sentence)*, and

c) There are ten apples and oranges in total *(relative quantity sentence: combination story type)*.

2.1.2 Forward-thinking and Reverse-thinking Problem

An arithmetical word problem includes two kinds of numerical relations: story operation structure and calculation operation structure. Story operation structure is the equation expressing the numerical relation according to the story, while calculation operation structure is the equation used to derive the required number in the assignment.

Based on this relation, there are two groups of problem in arithmetical word problems: forward-thinking problem and reverse-thinking problem. In forward-thinking problem, a story represented in the problem has the same structure with the calculation to derive the answer, while in reverse-thinking problem, the story and the calculation operation structures are different (Hirashima and Kurayama, 2011).

For example, in the following problem:

There are seven apples. Three apples were eaten. There are several apples.

How many apples are there?

Based on the sentence "Three apples were eaten", we understand that the story focuses on "decrease" number of an object. The story operation structure is "7-3=?", and the calculation structure is also "7-3(=?)", which can be found easily by reading the story in order from the first sentence. Since the two structures are the same, this type of problem can usually be solved easily by the learners.

Meanwhile, in the following problem:

There are seven apples. Several apples were eaten. There are three apples. How many apples were eaten?

We can derive the story operation structure as “7 - _ = 3”, and the calculation operation as “7 - 3 = _”. Since the two structures are different, a learner is required not only to understand the story but also to derive the calculation operation structure from the story. This type of problem is called “reverse-thinking problem”.

2.1.3 Triplet Structure Model

Triplet Structure Model, as shown in Figure 2-1, describes the components of arithmetic word problems and the basic structure of them. In this model, an arithmetic word problem is defined that it consists of three sentences including different quantities and each sentence must represent only one quantity with the meaning of them in the story. The three sentences include two "independent quantity sentences" and one "relative quantity sentence". Independent quantity sentences describe numbers of objects, for example, “There are 5 red apples.”, “There are 3 green apples.” and so on. Relative quantity sentences describe the relation between the other independent quantity sentences, for example, “There are 8 apples altogether.”, “2 apples are eaten.” and so on. The combinations of different sentences form different stories and assign different roles for each sentence (Hirashima et al, 2014).

An arithmetic word problem leads two types of numerical formula: one represents the story of the problem and the other represents the calculation to solve the problem. In the example, [There are 5 apples. 3 apples are eaten. There are some (?) apples.], the former is 5-3=? and the latter is 5-3=?. On the other hand, if the problem is [There are "?" apples. 2 apples are eaten. There are 3 apples.], the former is ?-2=3 and the latter is 3+2=?. The two types of formula are different. 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.

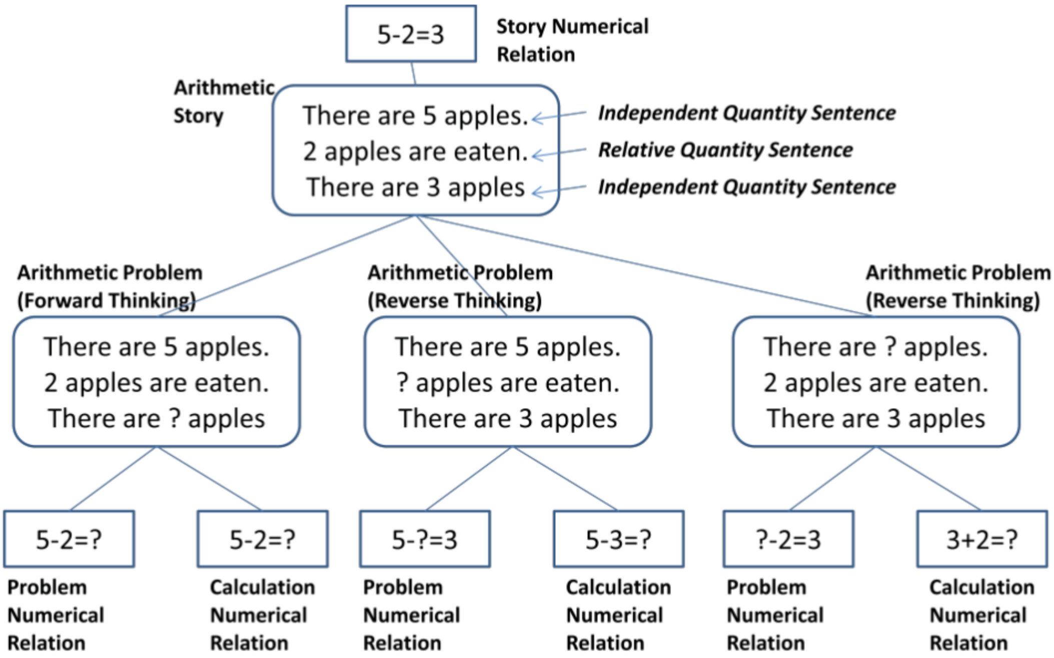


Figure 2-1 Triplet Structure Model (Hirashima et al, 2014)

2.2 Task Model of Problem Posing

Based on the consideration of problem types, the task model of problem posing as sentence-integration is shown in Figure 2-2 (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. Each element has some options. Triplet Structure Model describes the essential conditions to form a problem and defines problem posing as a task to choose an option in each element from all the possible combination.

First of all, this task model illustrates all the possible valid combinations of the elements and direct and indirect relations among them. The elements are related with neighbors in order. For example, a calculation formula, "x+y" or "x-y", is directly related to story formulas, not to story types and problem sentences.

When one element is decided, the other elements might be restricted. For example, if story operation is decided on for one of them, possible story types are narrowed to only two. For example, if the story operation of a problem is "?+y=x", the possible story types are only combination or addition. On the other hand, even if calculation operation is decided, the possible story types are not narrowed, that is, all the story type can be made with the calculation operation.

About problem sentences, this figure does not illustrate the options. This element includes three sub-elements: sentence structure, concept structure and number structure. *Sentence structure* is the composition of sentences. As defined in Triplet Structure Model, an arithmetic word problem must consist of two independent quantity sentences and one relative quantity sentence. The type of relative quantity sentence is related to story types. *Concept structure* requires the consistency of objects in the sentences. For example, if story type is increase or decrease, objects in three sentences must be the same. On the other hand, if story type is combination or comparison, objects in the independent quantity sentences are different and both of them are in the relative quantity sentence. *Number structure* requires the consistency of numbers in the problem. Each number in the problem must be derived from the other numbers.

Problem posing is a task to an option in each element following the relations in the task model. In addition to that, assignments in Monsakun provide restrictions on formula and story type. For example, the assignment shown in Figure 2-2 requires posing a problem related to the formula "7-3" and decrease story type. Based on the task model, what learners are required to think in this assignment is to find a combination of options in the elements that satisfy the requirement. In this case, whether a learner think the required formula is calculation formula or story formula, the learner can pose a decrease story type, because both of the calculation operation "x-y" and the story operation "x-y=?" are related to decrease story type. On the other hand, if the requirement is the formula "7-3" and increase story type, it is important to identify whether the formula is calculation operation or story operation. If the required formula is story operation, it is not related to increase story type. Only when the formula is calculation operation it is related to the story type. In this case, for example, the problem {There are 3 apples / ... apples were added / There are 7 apples.} satisfies the requirement.

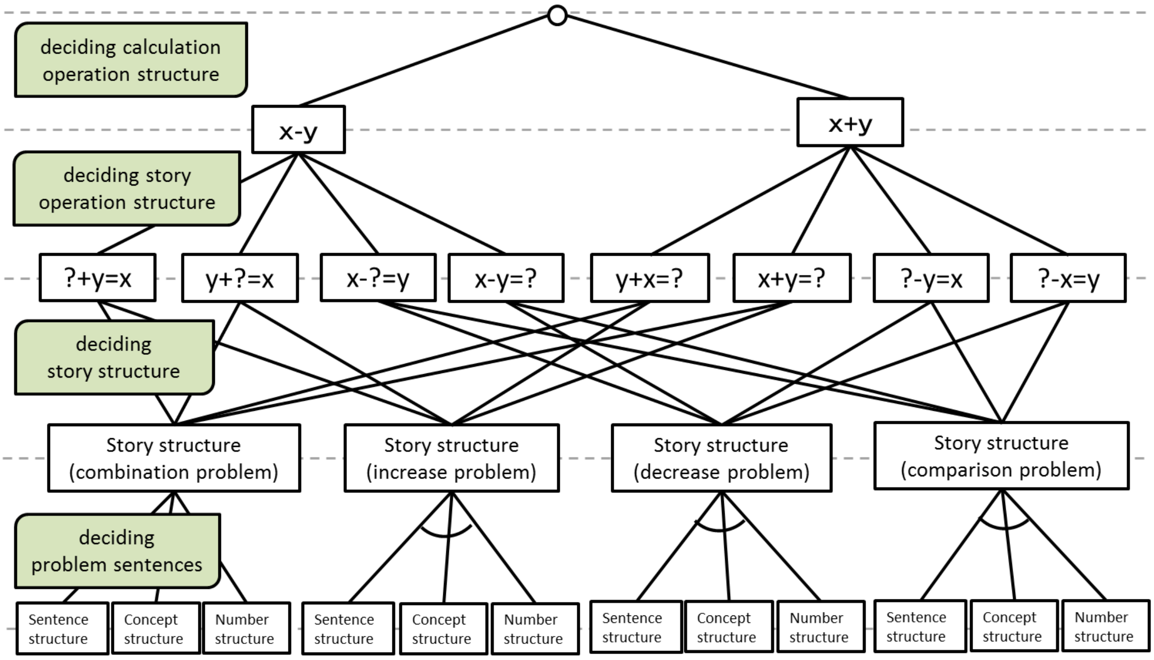


Figure 2-2 Task model of problem-posing as sentence integration (Kurayama & Hirashima, 2010)

2.2.1 Types of Story

Riley et al's (1983) hypothesis stated that children's understanding of simple word problems can be modeled in four schemas. Three interrelated quantities are included in each of the schemas with the equality a + b = c, which is sufficient to represent a one-step arithmetic word problem. The four schemas are called Combine, Change-In (increase), Change-Out (decrease), and Compare (Kintsch & Greeno, 1985; Cummins, 1988).

Monsakun is developed based on the four schemas (we call them story types) and the sentence cards conforms to the principle of Triplet Structure Model. Monsakun provides a way for students to touch and work directly with the structure of arithmetic word problem. Moreover, the dummy/distractor sentence cards give students opportunity to distinguish extraneous and necessary information in a word problem, a practice rarely seen in classroom situation.

There are four types of stories in Monsakun's arithmetic word problems. Addition story is categorized into two types: increase story and combination story, while subtraction story is categorized into two types: decrease story and comparison story. Each story is composed of two independent quantity sentences and one relative quantity sentence. An independent quantity sentence can be used in any problem, however, a relative quantity sentence is only used for one specific story problem. Example of posed problem for each type of story is shown in Figure 2-3. The yellow sentence cards are independent quantity sentences, and the red sentence cards are relative quantity sentences.

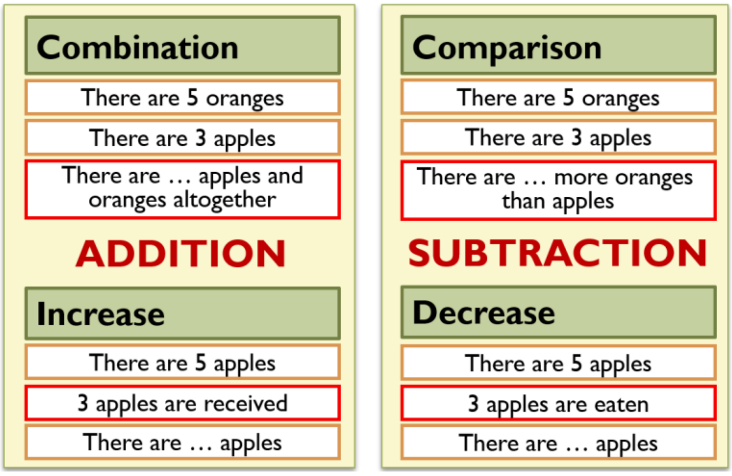


Figure 2-3 Four Types of Story in Monsakun

2.2.2 Types of Constraint

Based on the task model of problem-posing and the format of assignments in Monsakun, there are five main constraints that must be satisfied in posed problems. They are (1) calculation, (2) story type, (3) number, (4) concepts/objects, and (5) sentence structure.

When a posed problem satisfies all five constraints, the required problem in the assignment is correctly posed, and it is called “meaningful answer”. On the other hand, when a posed problem satisfies less than five constraints, it is not a correct answer. However, the posed problem still partially fills the requirements in the assignment, thus it is a “meaningful answer” as well. The unsatisfied constraints represent the cause of the inadequateness for the requirements. Lastly, when a posed problem satisfies no constraint, it is a meaningless and incorrect answer. In Chapter 4, the concept of meaningful and meaningless answer based on satisfied constraints is illustrated through examples.

2.3 Monsakun as Learning Environment for Problem Posing

Figure 2-4 shows the interface of Monsakun. In each assignment Monsakun provides learners with a requirement to form a problem and a set of sentence cards presented in a random order. By selecting and arranging appropriate cards, learners pose the arithmetic word problem fulfilling the requirement. In the problem posing activity, learners do not create their own problem statements, however they are required to interpret the sentence cards and integrate them into one problem. This activity is called "problem posing as sentence-integration" (Hirashima & Kurayama, 2011). Monsakun adopts the analysis of semantic structures in arithmetic word problems by Riley et al. (1983) and the process model of problem-solving of the word problems by Kinstch & Greeno (1985). Its problem posing assignments encourage learners to distinguish the extraneous information in word problems, which is more difficult than solving a standard word problem, as stated by Muth (1992).

When the learner has arranged three cards and push the check button, the system will analyze the answer. If the learner answers correctly, he or she will proceed to the next assignment. If his answer is wrong, the system will give feedback, and the learner can correct his mistakes.

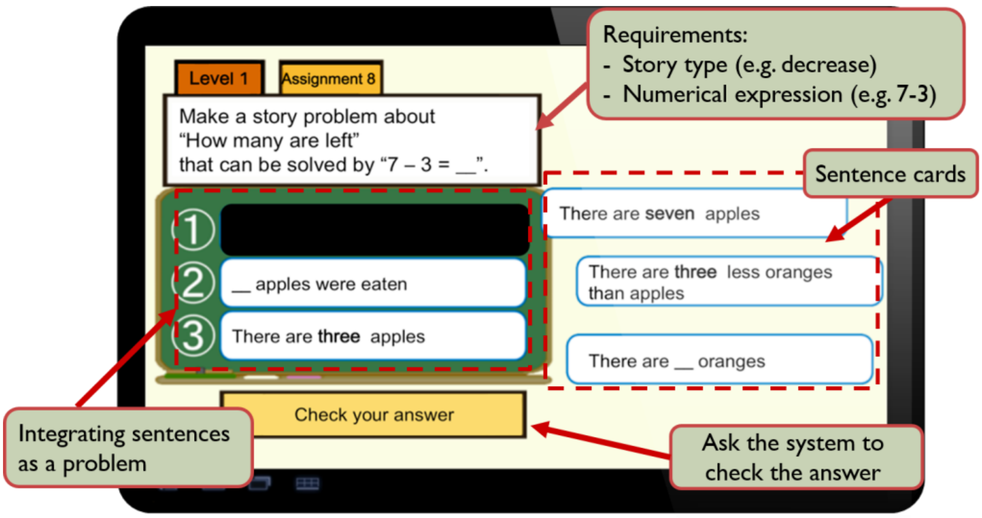


Figure 2-4 Interface of Monsakun

The practical use of Monsakun has been conducted in several elementary schools (Hirashima et al., 2008a; Hirashima et al., 2008b; Yamamoto et al., 2012; 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.

2.3.1 Problem Levels

In Monsakun Touch for addition and subtraction, there are six levels with increasing difficulties, as shown in Table 2-1. From Level 1 until 4, the four categories of problems above are included with the forward-thinking problems type. In Level 5, reverse-thinking problems are being introduced.

2.3.2 Assessment of Errors

The system evaluates combination of cards, then gives appropriate feedback regarding to types of mistake the learner made. According to the task model of problem posing in Monsakun, the errors are identified into seven categories, as described in Table 2-2.

The flowchart of error assessment is shown in Figure 2-5. When students make incorrect problems, the system gives a feedback message in accordance to the type of error that the student committed.

Table 2-1 Detailed level assignments in Monsakun

Level	Number of Assignments	Type of Problem Thinking	Provided Formula	Story Types
1	12	Forward	Story	Combination, Increase, Decrease, Comparison
2	3	Forward	Story	Increase + Combination
3	12	Reverse	Story	Combination, Increase, Decrease, Comparison
4	3	Reverse	Story	Increase + Combination
5	12	Reverse	Calculation	Combination, Increase, Decrease, Comparison
6	12	Random		

Table 2-2 Types of mistake in Monsakun

Code	Types of Mistake
1	Story operation structure is different
2	Calculation operation structure is different
3	Story & calculation operation structure are different
4	Concept structure is different
5	Number structure is different
6	Concept & number structure are different
7	Story operation structure isn't built

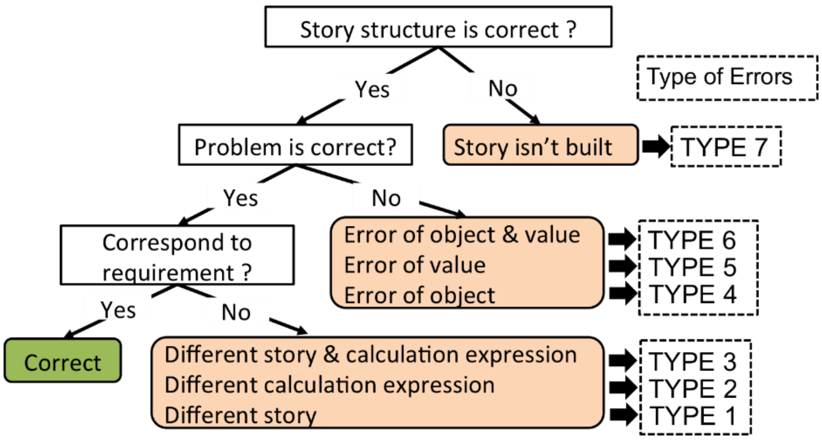


Figure 2-5 Flowchart of error assessment in Monsakun

CHAPTER 3

ANALYSIS OF LEARNERS' THINKING PROCESS IN PROBLEM-POSING EXERCISES (Focus: Japanese University Students)

Summary: In this research, we conducted analysis from the log data of university students using Monsakun to understand students' thinking process while posing arithmetical word problems. Eleven university students participated in the experiment. In the first step of analysis, we focused on the first sentence card selected in the process of posing a problem. We found that the selection changed based on different type of approach, type of story and students' exercise experience. We also consider commonly occurred mistakes and students' thinking process from frequent paths taken by students in one of the problem. This result is an important step towards building elaborate process model of problem-posing and adaptive support of the process.

3.1 Introduction

Through previous practical use, we observed different ways of sentence selection in problem-posing process by the students. We assume that it is caused by the different way of thinking depending on the nature of problems and learner's understanding. Therefore, by examining the selection process of sentences, we aim to infer about a learner's thinking process in problem-posing.

Problem posing in Monsakun is defined as integration of provided sentences into one problem. Learner's assignment is to choose appropriate cards from several sentence cards provided by the system in order to fill the requirement of numerical expression and story type. This can be considered as search problem. While it is difficult to trace 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 section, the analysis of Monsakun log data from an experiment of Monsakun used by eleven undergraduate students from Faculty of Education is reported. Although Monsakun is intended for elementary school students, the subjects of this experiment are undergraduate students. The reason is that undergraduate students are supposed to be able to solve both forward-thinking and reverse-thinking problems rather easily, because they have already understood the structure of simple arithmetic word problems. They are only expected to learn how to make problems through the use of Monsakun.

On the other hand, elementary school students firstly learn about the problem structure through the use of Monsakun before they become able to pose problems, which takes several times of class schedule. Because the undergraduate students do not need to learn but only to recognize the problem structure, they are expected to show clearer changes in thinking process towards different problem types than elementary school students. For this reason, our study analyzed data from the experimental use of Monsakun by university students as the subjects. In the experiment, the subjects are firstly given explanation about the software, and then posed problems in a given time.

3.2 Research Questions

One important direction in investigation of problem posing activities is to examine thinking processes related to problem posing (Brown & Walter, 1990). As the next step of Monsakun development, the purpose of this study is to examine learners' problem-posing process and to develop technologies for identifying learners' thinking process. By identifying learners' thinking process, we will be able to provide a better individualized feedback based on understanding of each learner.

In this study, to address [RQ-1]: "Do learners pose problems in Monsakun with a consideration towards the sentence structure?", we examine how learners pose arithmetical word problems as sentence integration on Monsakun. Our assumption is learners do not choose sentence cards randomly - they arrange sentence cards based on some sort of thinking. In the analysis, as the first step toward analyzing problem-posing activity, we especially focus on what kind of sentence card was firstly selected by the learners.

The research questions addressed in this study are:

[RQ-1a] What is the tendency of learners' first selected sentence?

[RQ-1b] What is the tendency of mostly occurred type of mistakes?

[RQ-1c] How does the tendency of the first selected sentence change in different assignments?

[RQ-1d] How could learners' thinking process be inferred from the log data?

3.3 Methodology

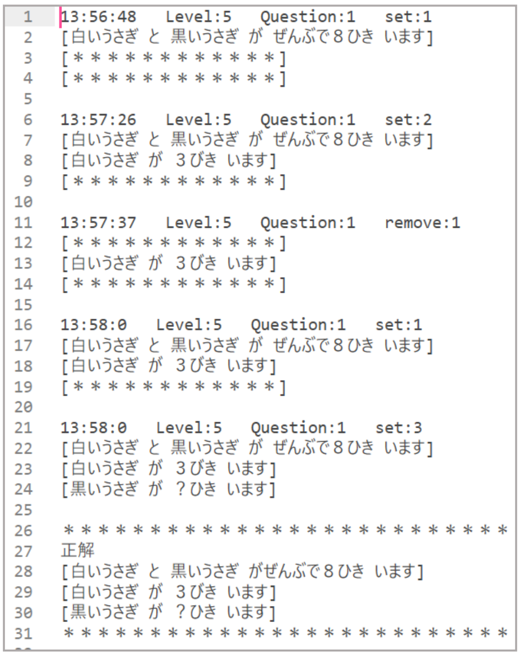
In this experiment, eleven undergraduate students from Faculty of Education used Monsakun. The students are firstly given explanation about the software, and then posed problems in a given time. The log data from each student are then translated into sequential data for further analysis.

Especially in this research, we focused to analyze students' log data in Level 1 and Level 5. Each level consists of 12 problems divided into four types of problems: combine, increase, decrease, and comparison problem. Problems in Level 1 are forward-thinking problems, while problems in Level 5 are reverse-thinking problems. The detailed assignments in each level is shown in Appendix A. We aimed to find out students' performance in these levels, and whether they had particular strategies regarding the different difficulties. Table 3-1 shows the size of log data for Japanese university students and Figure 3-1 describes an example of a problem posing sequence in Monsakun log data.

Our aim in this study is to examine learners' way of thinking from selection of sentence, especially the first selected sentence in each assignment. We analyzed the subjects' log data in assignments at Level 1 and Level 5 which require the subjects to pose forward-thinking problems and reverse-thinking problems, respectively. Both levels 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.

Table 3-1 Size of log data for Japanese university students

	Level 1	Level 5
Participants	11	11
Assignments	12	12
Posed problems (total)	160	409
Steps (total)	494	1,955
Steps per Problem (avg)	3.09	4.78
Steps per Assignment (avg)	3.74	14.81
Posed problems per Assignment (avg)	1.21	3.10



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13:56:48   Level:5   Question:1   set:1
[白いうさぎ と 黒いうさぎ が ぜんぶで８ひき います]
[＊＊＊＊＊＊＊＊＊＊＊＊＊]
[＊＊＊＊＊＊＊＊＊＊＊＊＊]

13:57:26   Level:5   Question:1   set:2
[白いうさぎ と 黒いうさぎ が ぜんぶで８ひき います]
[白いうさぎ が ３びき います]
[＊＊＊＊＊＊＊＊＊＊＊＊＊]

13:57:37   Level:5   Question:1   remove:1
[＊＊＊＊＊＊＊＊＊＊＊＊＊]
[白いうさぎ が ３びき います]
[＊＊＊＊＊＊＊＊＊＊＊＊＊]

13:58:0   Level:5   Question:1   set:1
[白いうさぎ と 黒いうさぎ が ぜんぶで８ひき います]
[白いうさぎ が ３びき います]
[＊＊＊＊＊＊＊＊＊＊＊＊＊]

13:58:0   Level:5   Question:1   set:3
[白いうさぎ と 黒いうさぎ が ぜんぶで８ひき います]
[白いうさぎ が ３びき います]
[黒いうさぎ が ？ひき います]

＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊
正解
[白いうさぎ と 黒いうさぎ がぜんぶで８ひき います]
[白いうさぎ が ３びき います]
[黒いうさぎ が ？ひき います]
＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊
```

Figure 3-1 Example of a problem posing sequence in Monsakun log data

3.4 Analysis and Discussion

3.4.1 First Selected Sentence

Problem posing in Monsakun is defined as integration of provided sentences into one problem. Learner's assignment is to choose appropriate cards from several sentence cards provided by the system in order to fill the requirement of numerical expression and story type. This can be considered as search problem.

Figure 3-2 illustrate a search space of an assignment in Monsakun which provides six sentence cards. The search space is a tree structure of combination of cards. Here, the root is the starting point and the numbers represent ID of cards, for example, the starting point is empty and the combination of cards 1, 2 and 3 indicates the correct answer. The nodes and arrows with bold line represents the paths of the learner's card selections during his problem posing activity. This learner committed mistakes twice and then got the correct answer. As shown in this figure, problem-posing in Monsakun is defined as a search problem in the structure of transition of card combinations. The rules for valid combination of the sentence cards are explained in the next section.

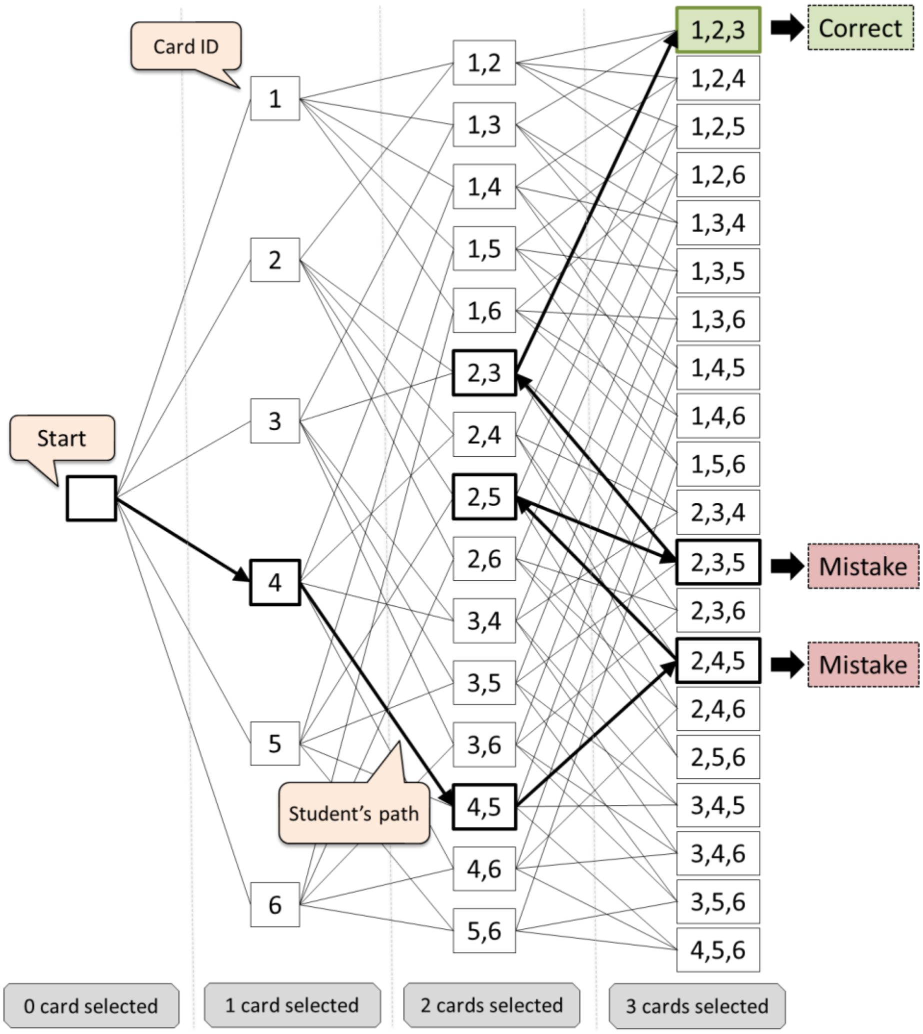


Figure 3-2 Example of learner's card selections shown in a graph

Using the same graph as the problem space, the mapping of log data from 11 university students in Level 5 Assignment 1 is shown in Figure 3-3. Black nodes and links represent the ones selected by the subjects, while gray ones represent the ones not selected. In this experiment, not all paths were observed in subjects' selection. Subjects only took some particular paths, which show that the card selections are not random. In addition, focusing on the card firstly selected by subjects, most of them chose Card 4 (8 subjects out of 11). In this assignment, there is a decided tendency based on some sort of thinking. If we can clarify the tendency for learners to choose a specific first sentence card, it will be useful to diagnose learners' understanding. Therefore, as the initial step of analysis of students' thinking process, this study aims at revealing the characteristics of first selected sentence card [RQ-1a].

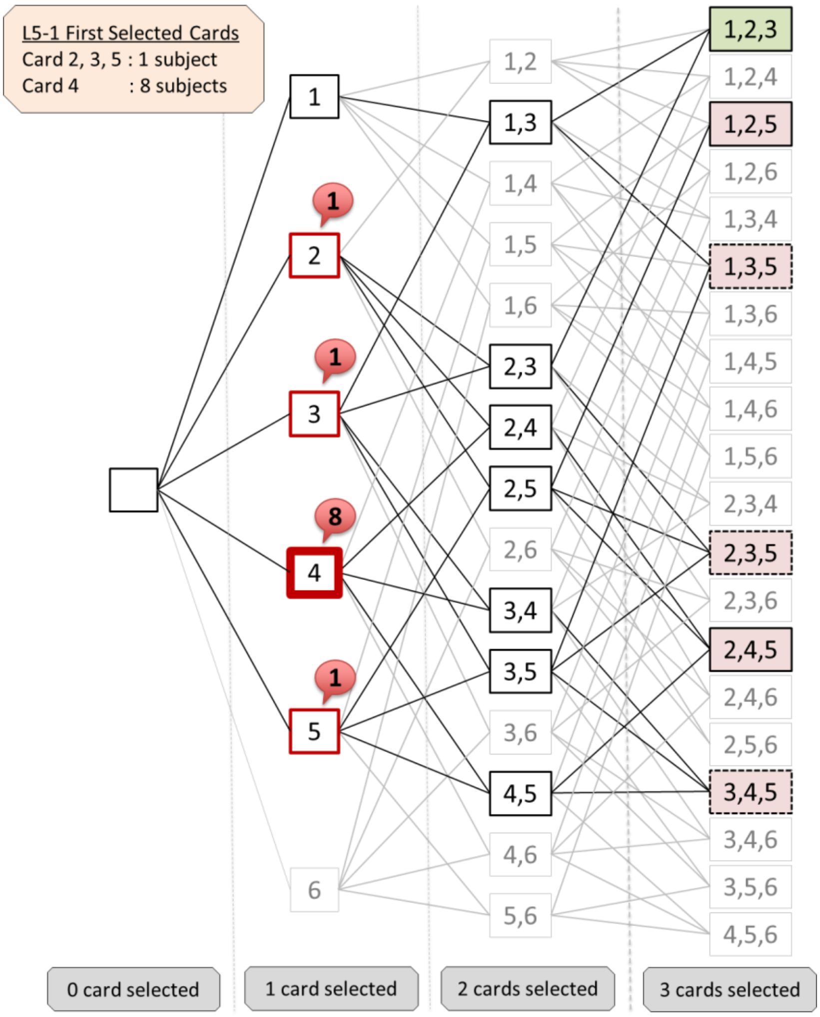


Figure 3-3 University students' sentence card selection in Level 5 Assignment 1

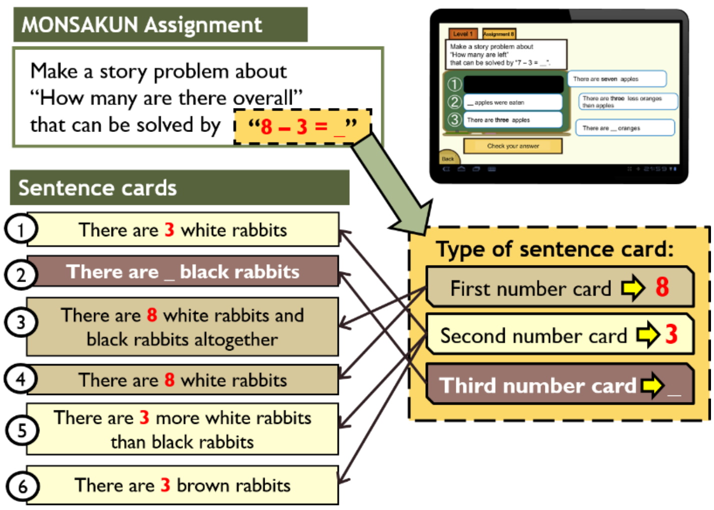


Figure 3-4 First, second, and third number card

The sentence cards in Monsakun contain different number according to the numerical expression in the given assignment. Figure 3-4 illustrates the concept of sentence cards in Monsakun. For example, in an assignment "Make a story problem about 'how many are there overall' that can be solved by 8 – 3 = _". In Monsakun, several sentence cards with numbers are provided to the subjects. The cards are distinguished by the order of numbers in the required calculation expression. If a card contains the first number in the required expression, for example, 8 in the example above, it is called *"first number card"*. Similarly, if it contains the second number 3 or the third number _, it is called *"second number card"* or *"third number card",* respectively. One of the numbers in every assignment is an unknown number, which is represented by the blank mark.

On the other hand, the *"first selected sentence"* card is related to subjects' posed problem (Figure 3-5). For example, using the same assignment in Figure 3-4, Among 11 university students, there were one person each that selected Card (2) There are _ black rabbits; Card (3) There are 8 white rabbits and black rabbits altogether; and Card (5) There are 3 more white rabbits than black rabbits. Meanwhile, most students apparently firstly selected Card (4) There are 8 white rabbits; and none of the students selected Card (1) nor Card (6) as their first sentence card.

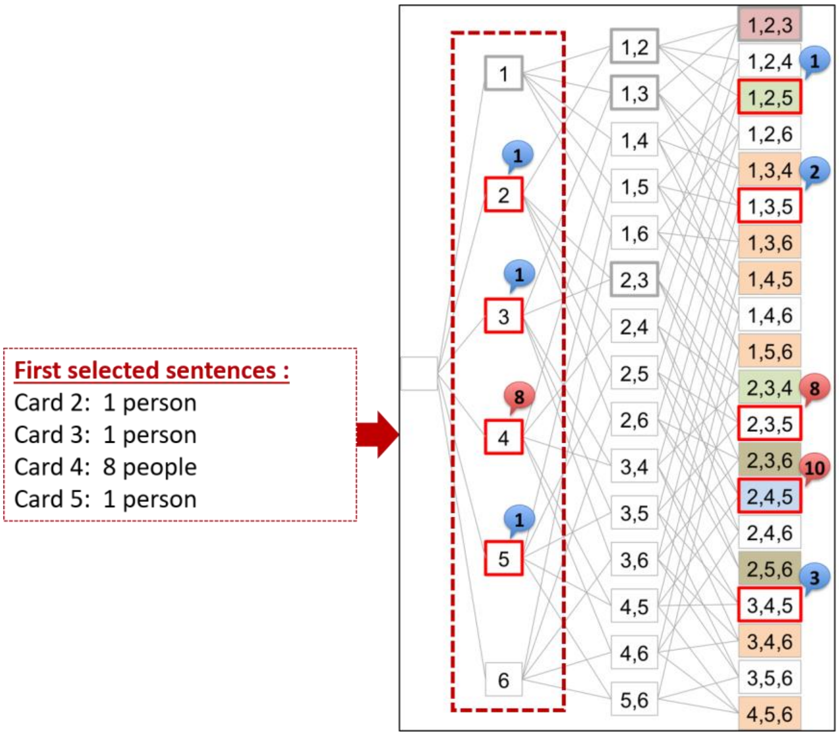


Figure 3-5 First selected sentence

From the analysis of all subjects' first card selection in Level 1 and Level 5 assignments, we found that the proportion of each sentence card to be selected firstly are entirely not even. Table 3-2 shows the proportion of first card selected by subjects in Level 1 and 5. In every assignment, only one or two cards are significantly chosen by them. We found that there is a bias against first selected card. This finding proves our assumption that subjects did not choose a card randomly, but with some sort of approach.

Table 3-2 Percentage of first selected sentence by the subjects

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

Furthermore, we found different trends of first card selection between Level 1 and 5. We presume that this difference appeared because subjects had different approach to pose either forward-thinking or reverse-thinking problems. In forward-thinking problem, the approach to order cards following the order of numbers in the numerical expression can be applied easily. However, in reverse-thinking problem they cannot 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.

3.4.2 Most Commonly Occurred Mistakes

3.4.2.1 Story Operation Structure Isn't Built

Table 3-3 shows the amount of mistakes made by students in Level 1 and Level 5 [RQ-1b]. The biggest number of mistake is type 7 (story operation structure isn't built), which shown that some students did not understand the correct composition of story operation structure. According to Table 3-2, 68% of mistakes made in Level 1 and 53% in Level 5 are type 7.

For example, in Level 1 Problem 3, the problem given is a combination problem that can be solved by 4+5. The cards are:

1. There are 4 boys
2. There are 5 girls

3. There are ? boys and girls altogether
4. There are ? boys
5. There are 4 more boys than girls

Table 3-3 Amount of mistakes made by students in Level 1 and Level 5 (%)

Type of Mistake	Level 1 (%)	Level 5 (%)
1. Story operation structure is different	13	27
2. Calculation operation structure is different	6	8
3. Story & calculation operation structure are different	0	0
4. Concept structure is different	6	2
5. Number structure is different	6	10
6. Concept & number structure are different	0	0
7. Story operation structure isn't built	69	53

Students made mistake type 7 by choosing cards 235.
2. There are 5 girls
3. There are ? boys and girls altogether
5. There are 4 more boys than girls

The selected cards consist of one existence sentence and two relational sentences, while to pose a problem, two existence sentences and one relational sentences are needed. Therefore, the story operation structure could not be built using cards 2, 3, and 5.

3.4.2.2 Confusing Story Structure and Calculation Operation

The second biggest number of mistakes according to Table 3-3 is mistake type 1 (story operation structure is different). In other words, students tend to confuse story operation structure and calculation operation structure. There were 13% of Level 1 mistakes and 27% of Level 5 mistakes of type 1.

For example, in Level 5 Problem 4, the given problem is an increase problem which can be solved by 12-8. Here, the order of cards is important. The cards are:
1. There are ? sparrows
2. 8 more sparrows come
3. There are 12 sparrows
4. There are 8 sparrows
5. A number of ? sparrows fly away

Students made mistake type 1 chose cards 354:

3. There are 12 sparrows
5. A number of ? sparrows fly away
4. There are 8 sparrows

These cards have correct calculation operation, however the story structure operation is wrong. The problem asked for increase problem, however cards 354 is a decrease problem.

3.4.3 Change of Approach through the Exercise

In the previous section, we have presumed that subjects had different approach to solve forward-thinking and reverse-thinking problems. 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 [RQ-1c]. We especially analyzed subjects' selection in Level 5 assignments, where they posed challenging reverse-thinking problems.

Table 3-4 shows the characteristics of first selected sentence card from each assignment at Level 5 that has marginal or significant difference in number of selection from the average. These results were analyzed with binomial test to the amount of each card being firstly chosen or not in each assignment. Binomial test is an exact test of the statistical significance of deviations from a theoretically expected distribution of observations into two categories. Based on our assumption that students posed problems by selecting cards through a thinking process, we expect the distribution of firstly chosen cards to have a significant difference in comparison with other cards.

When firstly used Monsakun, subjects are given simple forward-thinking problems to pose at Level 1. From the analysis mentioned in Section 3.4.1, we found that they first simply chose a sentence card with the first number in the required numerical expression ("first number card"), and then proceeded to choose other appropriate cards. This approach worked well for assignments in Level 1, where all of the assignments are forward-thinking problems.

Table 3-4 Result of binomial test of first selected sentence in Level 5 assignments

No	Type of story	Order of assignment	Type of first selected sentence	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)

When subjects arrived at the first assignment of Level 5, they initially approached the assignment with the same way of thinking in choosing the first sentence card. 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 did not work for reverse-thinking problems, because in the second assignment of Level 5 they tend to choose another type of card.

In a similar way, subjects changed their approach from the first assignment in a story type to the second and third assignment in the same story type. As shown in Table 2, in the first assignment in each type of problem, they generally took the simple approach to firstly select a "first number card" containing an existence sentence. Only in the case of comparison story there was no significant difference in cards selected by subjects in the first assignment. On the other hand, in the second and third assignments of the same type of story, they did not choose it as the first card. For example, in combination stories, most of them firstly did not select existence sentence, but "first number card" containing relational sentence. This is also the same as in the decrease story type.

Meanwhile, in the case of increase stories, we did not found any evident change between the assignments. At the second assignment they tend to select "second number card" containing existence sentence (shown by a marginal p-value), while at the third assignment they took the simple approach just like in previous levels of forward-thinking problems.

Furthermore, in comparison stories, there is no trend in first card selection at the first assignment. However, at the second and third assignment, there is a trend to select "third number card", that is a blank mark, containing a relational sentence. Consequently, we observed that there is a change of approach in comparison story compared to the previous story types.

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. As shown in Table 3-4, trends of first card selection are different between the first assignment and the rest in the same story type. 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 3-5 Average of steps and mistakes in Level 5 assignments

Story Type	**Average No. of Steps**		**Average No. of Mistakes**	
	Assignment		Assignment	
	1st	2nd & 3rd	1st	2nd & 3rd
Combination	11.60	4.20	1.5	0.3
Increase	45.50	16.50	8.4	1.4
Decrease	24.90	16.30	3.3	1.9
Comparison	10.00	9.80	1	0.5

These changes of approach seem to bring a good effect to subjects' thinking process in posing reverse-thinking problems. Our analysis of the average of steps and mistakes in Level 5 problems showed that in comparison to the first assignment of each story type, the average of steps and mistakes in the second and third assignments of the same story type are mostly decreased, as shown in Table 3-5.

3.4.4 Students' Thinking Process from Log Data

Why do students' mistakes occur? Some mistakes seem like careless mistake or a result of just trial and error, others seem like a results of misunderstanding of the structure of arithmetic word problems. This study aims to infer learners' thinking process by clarifying relationship between mistakes and behavior of students from the analysis of log data [RQ-1d].

Using the graph of problem space in Section 3.4.1, the following Figure 3-6 shows an example of assessment of mistakes using learners' path. As an example, five types of mistake occurred in Level 5 Assignment 1 are shown in the figure: Type 1 (Story operation structure is different), Type 4 (Concept structure is different), Type 5 (Number structure is different), Type 6 (Concept & number structure are different) and Type 7 (Story operation structure isn't built).

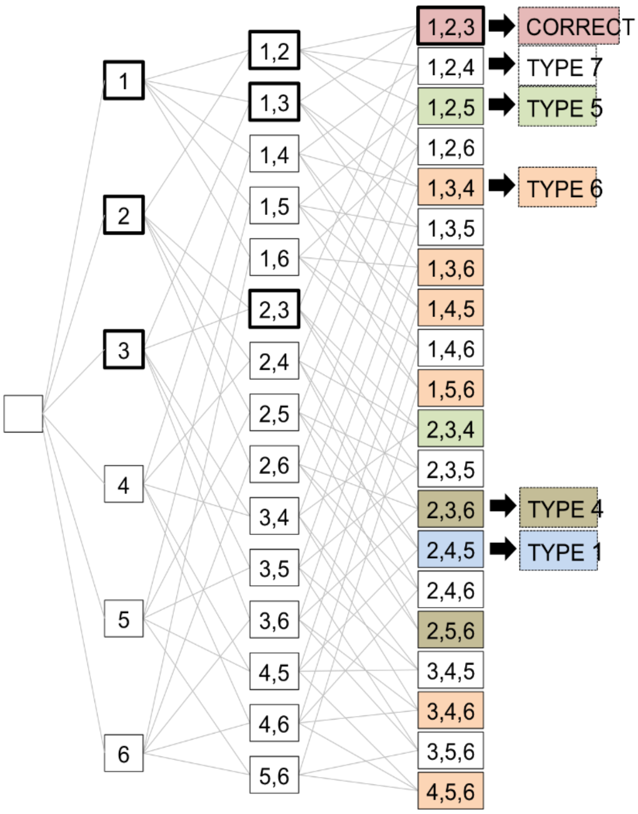


Figure 3-6 Assessment of mistakes using learners' path

Figure 3-7 show five frequent paths taken by students in Level 5 Assignment 1, where the problem given is a combination problem that can be solved by 8-3. The sentence cards are:

1. There are 3 white rabbits
2. There are ? black rabbits
3. There are 8 white rabbits and black rabbits altogether
4. There are 8 white rabbits

5. There are 3 more white rabbits than black rabbits
6. There are 5 brown rabbits

The correct answer is the following combination of cards 123:

1. There are 3 white rabbits
2. There are ? black rabbits
3. There are 8 white rabbits and black rabbits altogether

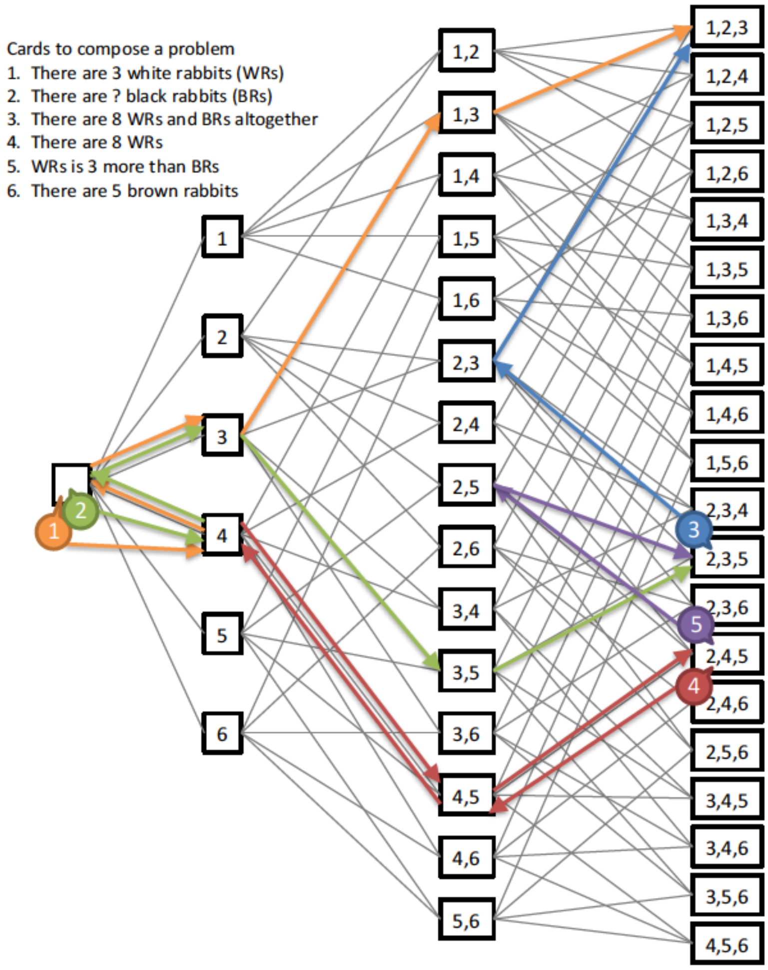


Figure 3-7 Five frequent paths taken by students in Level 5 Assignment 1

In Figure 3-7, each node represents a combination of cards by the card numbers mentioned above. The leftmost node represents empty state (no card selected) and the rightmost cards represent a combination of three cards. Thick colored lines are paths frequently appeared in the log data, that is, frequent behavior of students in this problem.

Two paths among them, path 1 and 3 can get to the correct answer, while the other paths get to incorrect answers. Path 1 is the simple one to get the correct answer. However, many students choose Card 4 firstly and then remove it. This card is not necessary for the correct answer and this is an unnecessary step. This follows the tendency discussed in Section 3.4.1, where students usually choose a card with the first number in the equation.

Students who took path 2 firstly selected Card 4 (existence sentence), but then removed it and selected Card 3 (relational sentence) which is necessary for the correct answer. This is the same as path 1. However, the students then selected Card 5, which is also a relational sentence. Finally, Card 2 is selected, and the students arrived at the wrong answer 235. This choice has two relational sentence and only one existence sentence, which is the same type of mistake discussed in Section 3.4.2. This mistake is assumed to be caused by misunderstanding of basic structure, two existence sentences and one relational sentence; or confusion between existence and relational sentences.

Path 3 shows that students who chose wrong answer 235 could proceed to the correct answer 123 by omitting Card 5 (relational sentence) and choosing Card 1 (existence sentence). Students who took path 3 realized that one more existence sentence is needed to pose the correct problem.

Meanwhile, path 4 and 5 both started at the wrong answer 245:

2. There are ? black rabbits
4. There are 8 white rabbits
5. There are 3 more white rabbits than black rabbits

In this choice, the calculation operation is actually the same as given problem (8-3), however the problem type in answer 245 is comparison, while the given problem asked to pose a combination problem. This is one of the type of mistake discussed in Section 3.4.2. Student who took this path received feedback from the system which only tells them that the answer is incorrect. By such feedback, he or she is expected to be aware of the cause of the mistake and change his or her thought by himself.

Students who arrived at this type of wrong answer tend to have difficulties in finding the right answer, because they thought that their answer is already correct, as the calculation operation is the same as given problem. As seen in path 4, the students went back to choose Card 4 and once again arrived at the same wrong answer. Such students are assumed to only have naive understanding of the structure of arithmetic word problems such as that subtraction appear only in decrease and comparison problem, or just overlook the requirement of story type.

In path 5, the students arrived at another wrong answer of 235. Although this case is still wrong answer, they get an important step. He or she is supposed to be aware of that another relational sentence is necessary for the correct answer.

3.5 Summary

In this research, we have conducted analysis of Monsakun log data of university students' problem posing activity to investigate whether learners pose problems in Monsakun with a consideration towards the sentence structure [RQ-1]. From the analysis, we found that the proportion of first sentence selected in each assignment were different in several ways [RQ-1a]. In every assignment, only one or two cards are significantly chosen by the learners. The proportion of each sentence card to be selected firstly is not even, although the common approach is to select the first number card. Regarding the type of mistakes, students mostly made mistake of not building correct story operation structure or confusing story operation with calculation operation structure [RQ-1b].

The next analysis regarding the tendency of the first selected sentence shows a change throughout the learning process [RQ-1c]. In forward-thinking problems (Level 1), subjects generally used a simple approach to select "first number card". However, in reverse-thinking problems (Level 5), they changed the approach to select "second number card" or "third number card". Depending on the type of story and subjects' exercise experience, they applied different approach of first card selection. From this change of approach, we infer that learners who used Monsakun were able to recognize the difference problem structure in Monsakun. The recognition of the difference is important for learners to understand the nature of arithmetic word problems. Lastly, by analyzing the frequent path taken by students in one of the problem [RQ-1d], we found out that students did not take all possible paths, but only a select few, which shows that they pose problems with some sort of thinking. The common correct path and mistake paths were able to be explained with reasonings based on our proposed model. The analysis of university students' log data served as a preliminary study towards the next chapter, where we conducted a study of elementary students' log data.

CHAPTER 4

ANALYSIS OF LEARNERS' THINKING PROCESS IN PROBLEM-POSING EXERCISES (Focus: Japanese Elementary School Students)

Summary: In this research, we investigated problems posed by elementary school students in Monsakun to understand whether Monsakun encourages them to think about the structure of arithmetic word problems. The result shows that students did not pose problems randomly, but considered things first. We also found that the frequent errors are actually meaningful errors, and students tried to pose problems satisfying as many constraints as possible, which means they actually think about the structure to pose required problems in the assignments. 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 arithmetic word problems.

4.1 Introduction

Researches of problem posing environments generally reported effectiveness of the problem posing practice using evaluation method of pretest and posttest comparisons. It is necessary to further analyze the learner products using the data collected by the system to get better view of learner's problem posing process in order to capture learner's understanding of math and science concepts (Birch & Beal, 2008). The aim of this study is to investigate the learner products in problem posing, that is, posed problems. We argue that problem posing is an activity that promotes learners to think structurally about arithmetic word problems. By analysis of the products we evaluate that "learners have thought about the structure of problems" and "learners' thinking about the structure has been improved in accordance with the progress of exercise".

This study analyzes the posed problems on an interactive problem posing learning environment named Monsakun. Monsakun (means "Problem-posing Boy" in Japanese) is a computer-based learning environment to realize learning by problem-posing in a practical way for one operation of addition and subtraction. The purpose of Monsakun as a problem posing learning environment is to encourage students to not only pose problems, but also to understand their structural nature. Monsakun provides learners with a novel way to promote learning by problem posing and it 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. This research discusses the validity of problem posing as sentence-integration in terms of learners' activity, because problem posing task in Monsakun is conducted by making a combination of given sentences, which at first glance seems not to require deep thinking.

4.2 Research Questions

There are two main points to be discussed in this paper: one is whether learners pose the required problems by chance, and the other is how learners can get to the correct answer if they do not get to it by chance. This study tests the randomness of learners' answers in Monsakun and analyzes the trend of them, especially, whether they focus on the structure of arithmetic word problems.

First, in Monsakun, the process of posing a problem is conducted by the combination of given sentences. Thus, theoretically, it is possible for learners to pose problems in random way and they can also get to correct answers stochastically, which means that they might not consider anything 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 investigate that students do not pose problems in a random way, but with some consideration, by analyzing the satisfied constraints in learners' posed problems.

Second, Monsakun is based on a model called “Triplet Structure Model”, which describes the structure of arithmetic word problems (Hirashima et al., 2014). This model defines the components of arithmetic word problems and the necessary conditions of simple arithmetic word problems. These conditions also become the constraints learners must satisfy in problem posing. To address [RQ-2]: “In what way the trends of posed problems by learners could be explained with the Triplet Structure Model?”, this study investigates the trends of posed problems with regards to the constraints, that is, how many constraints are satisfied in them in practical uses of Monsakun and how the tendency change in different assignments.

Based on this purpose, we defined the research questions as:

[RQ-2a] Which constraints were satisfied in elementary school students’ posed problems?

[RQ-2b] How does the tendency of satisfied constraints change in different assignments?

This study is limited only to the type of arithmetic word problems used in Monsakun. The emphasis of analysis of students’ problem posing related to Triplet Structure Model distinguish this study from the other problem posing research.

4.3 Methodology

4.3.1 Experiment Subjects

To conduct the analysis, we examine the log data of Monsakun practical use from 39 first grade students in a Japanese elementary school. The practical use, as described in Yamamoto et al. (2012), was conducted in 9 class sessions and Monsakun was used in 7 class sessions of them, 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 was involved in every session. The teacher monitored students’ progress in real time using Monsakun Analyzer and gave assistance to students who seem to have difficulties in progressing with problem posing task in Monsakun. During the teaching activity, the teacher provided one assignment to all students with the same form of problem posing in Monsakun and let them challenged the assignment together through active discussion by all students.

During seven class sessions, students practiced all the levels in Monsakun. In Monsakun, learners try assignments step by step from the first one. A learner can move on to the next assignment when he or she gets successful in the provided one. He or she must continue to try the same assignment until getting successful in the required problem posing. In each class session, students try only one level and repeat it when they finished.

4.3.2 Data Analysis Framework

This study investigates learners' trends of posed problems using the viewpoint of Triplet Structure Model. Firstly, the rate of finished students and the average of steps and mistakes in each level is reported to show students' performance in posing problems with Monsakun. Next, we selected frequent error combinations and investigated the satisfied constraints. Then we analyze the proportion of the numbers of satisfied constraints in actual students' answer and possible assignment setting using Chi-square test. If learners pose problems randomly, the proportion would be close to the proportion in the assignment setting. Afterwards, we analyze the difference of the proportions among assignments in the same story type. If learners pose problems with some consideration, the proportion would reflect their thoughts.

We analyze students' 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 in each, and do not include assignments of all the story type. The detailed assignments in each level is shown in Appendix A. Table 4-1 shows the size of log data for Japanese elementary school students and Figure 4-1 describes an example of a problem posing sequence in Monsakun log data.

4.4 Analysis and Discussion

4.4.1 Students' Performance between Levels

The rate of finished students and the average of steps and mistakes in each level is shown in Figure 4-2. 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 Level 3.

Table 4-1 Size of log data for Japanese elementary school students

	Level 1	Level 3	Level 5
Participants	39	39	39
Assignments	12	12	12
Posed Problems (total)	2,592	1,682	5,010
Steps (total)	11,603	6,903	23,612
Steps per Problem (avg)	4.48	4.10	4.71
Steps per Assignment (avg)	24.79	14.75	50.45
Posed problems per Assignment (avg)	5.54	3.59	10.70

id	date	time	lv	asg	trial	ope1	tgt	ans	jdg	err
1	2012-02-08	113830	1	1	1	set	1	100	n	*
1	2012-02-08	113837	1	1	1	set	2	120	n	*
1	2012-02-08	113839	1	1	1	remove	2	100	n	*
1	2012-02-08	113840	1	1	1	remove	1	000	n	*
1	2012-02-08	113841	1	1	1	set	1	010	n	*
1	2012-02-08	113841	1	1	1	remove	1	000	n	*
1	2012-02-08	113842	1	1	1	set	1	001	n	*
1	2012-02-08	113842	1	1	1	set	2	201	n	*
1	2012-02-08	113844	1	1	1	set	3	231	s	0

Figure 4-1 Example of a problem posing sequence in Japanese elementary school students log data

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 4-2, 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.

4.4.2 Satisfied Constraints in Students' Posed Problems

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, we will examine students' posed problems in Level 5 to investigate the satisfied constraints in different story types [RQ-2a].

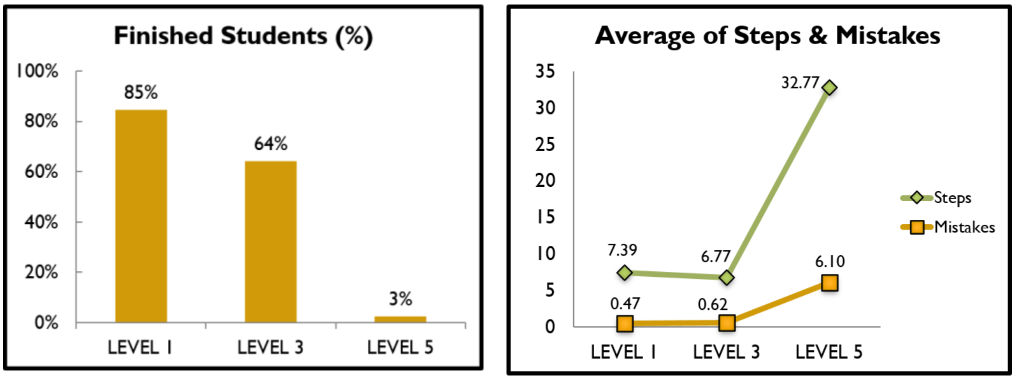


Figure 4-2 Comparison of Students' Performance in Level 1, Level 3, and Level 5

From students' posed problems, we selected frequent error combinations (>10%) and investigated the satisfied constraints. Because these combinations are incorrect answers, they automatically fulfill only four out of five constraints, whose percentages are shown in Figure 4-3. The result shows 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.

As explained in Section 2.2.2, these constraints are derived from the task model of problem posing, which is built according to the definition of arithmetic word problems in the Triplet Structure Model. From the result of analyzing the correlation between actual and possible satisfied constraints, our 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 sentence cards that satisfies the constraints.

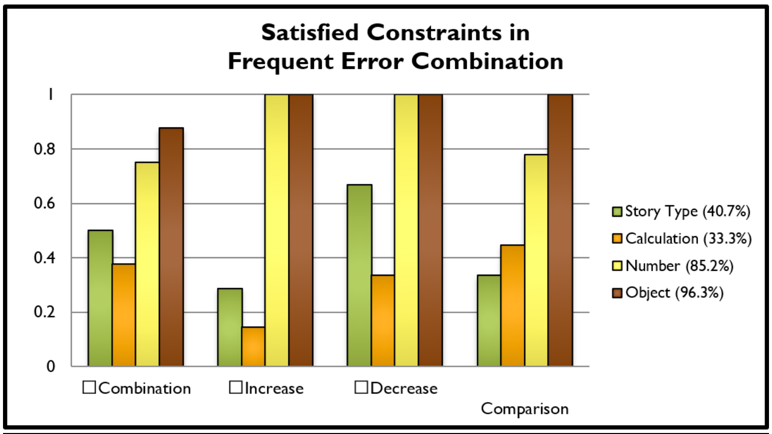


Figure 4-3 Satisfied constraints in frequent error combination

4.4.3 Change of Tendency in Satisfied Constraints

In this section, we examine the trends of problem posing in the practical use of Monsakun, especially, whether the tendency of satisfied constraints is changed during the use of Monsakun [RQ-2b]. 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.

Problems posed by learners are assessed whether these are meaningful or meaningless. Meaningfulness is evaluated by how much constraints they satisfy. Table 4-2 shows example of meaningfulness of posed problems (learner's answer). The first posed problem satisfied all constraints, so it must be meaningful. If a posed problem does not satisfy all the constraints but some, such as in the 2nd and 3rd posed problem, it is also meaningful. On the other hand, if a posed problem does not satisfy any constraint, as in the 4th problem, it is an incorrect and meaningless problem. To sum up, we define a meaningful problem as the problem that satisfies one or more constraints, and a meaningless problem as the problem that does not satisfy any constraint. In the analysis, we categorize posed problems and examine which kind of problem students have posed.

Table 4-2 Illustration of correct/incorrect and meaningful/meaningless posed problems

Assignment:

Make a word problem of "how many are there overall"

Sentence cards:

- There are 3 white rabbits
- There are _ black rabbits
- There are 8 white rabbits and black rabbits altogether
- There are 8 white rabbits
- There are 3 more white rabbits than black rabbits
- There are 3 brown rabbits

Learner's Posed Problem	Satisfied Constraints					Assessment
	Calcu-lation	**Story Type**	**Number**	**Object**	**Sentence Structure**	
There are 3 white rabbits There are _ black rabbits There are 8 white rabbits and black rabbits altogether	✓	✓	✓	✓	✓	- Correct problem - All constraint satisfied ➔ **MEANINGFUL**
There are 8 white rabbits There are _ black rabbits There are 3 more white rabbits than black rabbits	✓	X	✓	✓	✓	- Incorrect problem - 4 constraints satisfied ➔ **MEANINGFUL**
There are 8 white rabbits There are 3 brown rabbits There are _ black rabbits	X	X	✓	X	X	- Incorrect problem - 1 constraint satisfied ➔ **MEANINGFUL**
There are 3 white rabbits There are 8 white rabbits There are 3 brown rabbits	X	X	X	X	X	- Incorrect problem - No constraint satisfied ➔ **MEANINGLESS**

Table 4-3 Correlation analysis of satisfied constraints in the first attempt of posing problem in Level 5 assignments

Asg		Number of Satisfied Constraints (Actual: % / Possible: %)												Actual vs Possible	
		0	p	1	p	2	p	3	p	4	p	5	p	Chi-Sq	p
1	Actual	10.3		33.3		23.1				30.8		2.6		< 0.01	**
	Possible	20.0		47.5		22.5				5.0	**	5.0			
2	Actual	0.0		10.5		15.8				10.5		63.2		< 0.01	**
	Possible	15.8	**	44.2	**	30.0	+			5.0		5.0	**		
3	Actual	0.0		20.5		12.8				2.6		64.1		< 0.01	**
	Possible	6.7	+	41.7	**	31.7	*			10.0		10.0	**		
4	Actual			38.5		10.3				51.3		0.0		< 0.01	**
	Possible			75.0	**	18.3				5.0	**	1.7			
5	Actual			33.3		5.1				25.6		35.9		< 0.01	**
	Possible			76.7	**	15.0				6.7	**	1.7	**		
6	Actual			16.2		32.4		35.1		13.5		2.7		< 0.01	**
	Possible			53.3	**	40.0		3.3	**	1.7	*	1.7			
7	Actual			14.3		20.0		14.3		42.9		8.6		< 0.01	**
	Possible			38.3	*	53.3	**	3.3	*	3.3	**	1.7			
8	Actual			12.5		37.5				6.3		43.8		< 0.01	**
	Possible			46.7	**	48.3				3.3		1.7	**		
9	Actual			20.0		40.0		0.0		20.0		20.0		< 0.01	**
	Possible			63.3	**	28.3		1.7		5.0	*	1.7	**		
10	Actual	11.1		14.8		25.9				22.2		25.9		0.043	*
	Possible	6.7		41.7	*	31.7				10.0		10.0	+		
11	Actual	0.0		0.0		26.1				43.5		30.4		< 0.01	**
	Possible	11.7	+	38.3	**	40.0				5.0	**	5.0	**		
12	Actual	4.2		16.7		29.2				25.0		25.0		< 0.01	**
	Possible	20.8	+	37.5	*	31.7				5.0	**	5.0	**		

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

As explained in Section 2.2.2, 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 categorize posed problems in terms of the numbers of satisfied constraints, and then we examine the difference between the actual number of satisfied constraints in students' posed problems and the possible number of satisfied constraints in the assignment settings using Chi-square test. Table 4-3 shows the proportion of actual and possible number of satisfied constraints and the result of Chi-square test.

First, we investigate the number of satisfied constraints by all possible card combinations in each assignment. 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. The proportion is different depending on assignments. For example, in the 1st assignment, 20% of possible posed problems do not satisfy any constraint and about 70% satisfy only one or two constraints. On the other hand, in the 3rd assignment, only 6.7% do not satisfy any constraint, and from 4th to 9th assignments there all possible posed problem will satisfy at least one constraint.

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. Here, *actual number* means the number of card combination that is actually made by the students, that is, students' answers. Table 4-2 shows how many constraints that students satisfied in each assignment. For example, in the 1st assignment, most of posed problems satisfied 1 to 4 constraints, and there are only few students (2.6%) who satisfied 5 constraints, thus were able to correctly pose the required problem. On the other hand, in 2nd and 3rd assignments, more than half of the students successfully posed the required problem at their first attempt.

We apply Chi-square test to the counts of each number of satisfied constraints of actual and possible. If the actual number follows the proportion of possible number, the students' problem posing in Monsakun is just in a random way. As the result, there are significant difference between actual and possible numbers in all the assignments ($p<.05$). This shows that students pose problems not in random way.

In addition, we pay attention to examining which kind of problems posed more or less than the possible proportion. As the result, the proportion of problems satisfying less than 2 constraints are less than the possible and the ones satisfying more than 3 constraints are more than the possible. This shows the trend in which students try to pose problems satisfying more than 3 constraints.

The change of tendency in satisfied constraints could be observed through the change in the average of steps and mistakes in different story types. Figure 4-3 shows the graph of average steps and mistakes in Level 5 in different story type. The numbers shown are the total steps and mistakes from all students. There are four story types in arithmetic word problem: combination, increase, decrease, and comparison. Students are given three assignments for each story type, therefore the 1st to 3rd assignments are combination problems; the 4th to 6th assignments 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 the student would learn the problem structure in the second and third assignments in the same story type.

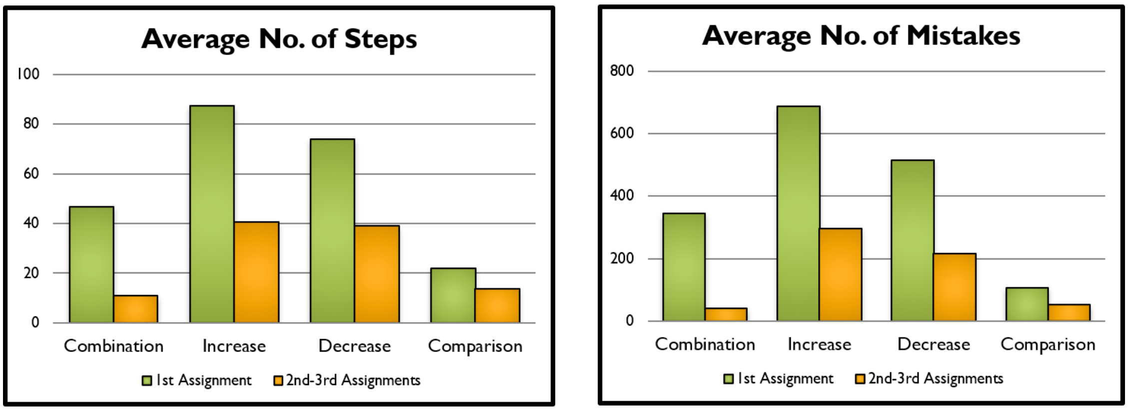


Figure 4-4 Average number of steps and mistakes in different story types in Level 5

As shown in Figure 4-4, 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 might change their thinking for posing problems.

From the result shown in Table 4-2, in 7 out of 8 assignments which are 2nd and 3rd assignments, the proportion of actual posed problems satisfying all five constraints are significantly higher than possible numbers, in spite of no significant difference in the ones which are the 1st assignments where the actual numbers are very low. It can be considered that the learners learn how to think in posing problem of the same story type and they become able to pose required problems easier in the next assignments. However, it calls for further investigation of problem posing process.

4.5 Summary

In this study, we have conducted analysis of posed problems in elementary school students' problem-posing activity with Monsakun in order to investigate learner's trend of posed problems [RQ-2]. The study was conducted by testing the randomness of learners' answers and analyzes the change of tendency in the posed problems. This is a case study of analyzing part of learners' thinking when they pose problem in a learning environment. Monsakun enables us to do such analysis because Triplet Structure Model defines the basic structure of arithmetic word problems and the constraints to form them.

This study is one step towards unveiling the work flow of students in problem posing learning environment (Birch & Beal, 2008). While Hirashima et al (2008) research showed not only students enjoyed learning problem posing with a computer-supported system but they also had better performance in math, the finding of this study shows the evidence that students were able to use the system for the intended purposes, which is to pose arithmetic word problems satisfying certain constraints. The focus of this study is on learner products of problem posing by investigating learners' average steps and mistakes and analyzing the satisfied constraints. From the analysis of satisfied constraints in frequent errors, we found that first grade students understand constraints of objects (96.3%) and numbers (85.2%), but faced difficulties in relating the numbers with the requirement of story type (40.7%) and calculation (33.3%) [RQ-2a].

Even though some learners took more steps in some assignments and pose incorrect problems, they are mostly meaningful answers because they satisfy some constraints, and many learners can get to the correct answer. We conclude that students change their thoughts to satisfy as many constraints as possible in posing problems, since the correlation analysis shows that the distribution of students' answer (actual) is different from the distribution in assignment setting (possible) [RQ-2b]. Moreover, in each story type, satisfied constraints tends to increase after they success to pose a problem in the first assignment.

These results can be considered as an evidence of the effectiveness of Monsakun for learning arithmetic word problems of one-step addition and subtraction. From the results, it can be inferred that the learners are aware of the structure and constraints of arithmetic word problems (either completely or incompletely) and try to satisfy the constraints in posing word problems with Monsakun. This process affects learners' understanding. The results are also important to provide support for the study of learner process in problem posing with Monsakun to determine group of learners with good or poor understanding of problem structure and to provide appropriate system assistance towards them.

CHAPTER 5

UTILIZATION ANALYSIS OF PROBLEM-POSING LEARNING ENVIRONMENT IN MULTIPLE LANGUAGES

Summary: Triplet Structure Model defines the structure of arithmetic word problems solved by one-step addition or subtraction. This study investigates whether the Triplet structure model works in languages other than Japanese. The analysis of the use of Monsakun in Japanese children and adults shows no significant difference between them. Another analysis of the use of Monsakun in English or Indonesian by non-native Japanese adults also shows no significant difference among them. We infer that through posing problem with Monsakun, regardless of age and language, subjects show some understanding of the structure of arithmetic word problem. Based on the results of data analysis and questionnaire, we suggest that the Triplet structure model is acceptable in multiple languages.

5.1 Introduction

The integration process of solving arithmetic word problem involves processing the linguistic meaning into arithmetical formulas which are similar in any language (Mayer, 1999). A study about the role of language and visuospatial representation in mathematical thinking shows that the exact arithmetic knowledge is stored in a language-specific format, while the quantity manipulation is done using a language-independent representation of number magnitude in visuospatial processing (Dehaene et al., 1999). Based on these, the expected role of Triplet-structure model is to describe the quantitative information to bridge the gap between the linguistic and the numeric information. The quantitative information consists of numbers with the meaning derived from the linguistic information represented as sentences of a story. Although the meaning of numbers is not represented in the numeric information expressed as equation, it is necessary to ensure the consistency between the linguistic and the numeric information. In this sense, Triplet-structure model must have a relationship with languages. If the relationship depends on Japanese, the model has a disadvantage for arithmetic word problems in any other languages than Japanese. This study investigates whether Triplet Structure Model can work with languages other than Japanese.

In the previous studies, Japanese children accept Monsakun in the practical study in the classroom (Hirashima et al., 2007; Kurayama & Hirashima, 2010). The analysis of the use of Monsakun by Japanese elementary school students and university students shows that the trends of correctness rate among levels in Monsakun are similar between children and adults (Hasanah et al., 2015b).

In this study, we compare the use of Monsakun in Japanese and ones in English and Indonesian to check the dependency of the relationship between the model and the linguistic information on a particular languages. First, to address [RQ-3]: "How do Japanese adults pose problems in Monsakun compare to Japanese elementary school children?", we conduct a more in-depth analysis of the learning data of Japanese native children and adult, steps and mistakes, satisfied constraints, and error occurrence, to clarify the Japanese native learners' thinking for posing word problem in Monsakun. Then, we analyze the use of Monsakun by the non-Japanese native university students speaking English or Indonesian and compare their learning data with Japanese ones to address [RQ-4]: "Is Monsakun in languages other than Japanese acceptable to non-native Japanese speakers?".

If the foreign university students can complete the tasks in Monsakun and the trend of the usage data are not different among languages, it can be considered that they can accept Triplet Structure Model as a basis for thinking arithmetic word problems and the model does not depend on Japanese. If non-native Japanese adults can pose problems in Monsakun as well as Japanese adults, as Japanese children have learned the nature of arithmetic word problems and have posed problems in the same manners as Japanese adults, it is hoped that Monsakun can contribute to English and Indonesian children's learning of arithmetic word problems as well.

5.2 Research Questions

The research is conducted based on the following research questions:

[RQ-3a] Is Triplet Structure Model acceptable by Japanese adults?

[RQ-3b] Are similar tendency of thoughts in Japanese children also found in the adults?

[RQ-4a] How do Indonesian and English foreign students pose problems in Monsakun?

[RQ-4b] Is Triplet Structure Model acceptable in Indonesian and English language?

Due to the limitation of resources, we have not been able to conduct a study for foreign children. In this study, we investigated Monsakun use as in an experimental study for university students in English and Indonesian language as a first step of the study of Monsakun in foreign languages.

5.3 Analysis of Monsakun Use by Japanese Children and Adults

In this section, analysis of Japanese children and adult subjects were conducted to answer the research question as follows:

[RQ-3a] Is Triplet Structure Model acceptable by Japanese adults?

[RQ-3b] Are similar tendency of thoughts in Japanese children also found in the adults?

We would like to show that adult subjects were able to accept the Triplet Structure Model and use Monsakun for learning by problem-posing, and their performance is similar to elementary school students.

5.3.1 Participants

In the first part of this study, the log data of problem-posing by Japanese university students is analyzed in comparison with elementary school students. Although the main targets of Monsakun are elementary school students, we aimed to investigate whether our learning environment is also acceptable to adults, in this case, university students, as the preliminary step of Monsakun study for international school children. The research question is whether the Triplet structure model acceptable by Japanese adult and whether children and adult have a similar tendency of thoughts in posing problems. In this part, 39 first grade of elementary school students and 51 university students participated in the practical use of Monsakun Japanese. All the participants were Japanese native.

5.3.2 Materials and Procedures

The practical use for elementary school students, as described in Yamamoto et al (2012), was conducted in 9 class sessions and Monsakun was used in 7 class sessions of them. The use by Japanese children was as the exercise of learning arithmetic word problems in the regular mathematics class. As usual exercise in classes, children engaged to use Monsakun and tried to get correct answers. Each session starts with Monsakun use for 5 minutes, usual classroom teaching activity for 35 minutes, and concluded by Monsakun use for 5 minutes. The teacher was involved in every session. During the practical use, the elementary school students use Monsakun as exercises in their usual classes. They also learn to pose arithmetic word problem together guided by a teacher. After conducting several classroom schedules with Monsakun, they became able to pose problems.

On the other hand, the university students have already learned arithmetic word problems and have the knowledge to solve basic word problems. They are only expected to learn how to pose problems with the use of Monsakun. In the experiment for the university students, they are first given the explanation about the software, and then they posed problems using Monsakun in a given time. The use of Monsakun was conducted as a part of lecture for learning of interactive learning environments. The tasks assigned to them in the lecture was to make a report about the mechanism and effectiveness of Monsakun based on both the teacher's explanation and the usage experience.

5.3.3 Design and Analysis

The log data from Level 1, Level 3, and Level 5 assignments were analyzed to measure subjects' problem-posing. Level 2 and Level 4 are omitted because they only contain three assignments from the same story type each, while other levels contain 12 assignments from four different story types.

Firstly, the average of steps and mistakes in each level is analyzed using ANOVA to show trends in different subject age/language. Then, the proportion of satisfied constraints in actual students' answer and possible assignment setting is analyzed using

Table 5-1 Analysis of average steps and mistakes (ANOVA)

	M (SD)	*Level 1*	*Level 3*	*Level 5*	*p*	*sig*
STEPS	JP kids	7.57 (3.25)	6.90 (2.80)	38.8 (16.46)	1.08E-30	**
	JP adult	5.51 (2.53)	4.24 (1.11)	7.93 (3.39)	1.61E-11	**
MISTAKES	JP kids	0.47 (0.52)	0.61 (0.54)	6.09 (2.59)	2.56E-34	**
	JP adult	0.33 (0.38)	0.18 (0.18)	0.79 (0.63)	5.09E-11	**

Table 5-2 Analysis of average steps and mistakes (Tukey-Kramer)

	STEPS		MISTAKES	
sig	JP kids	JP adult	JP kids	JP adult
L1-L3	no	no	no	yes
L1-L5	yes	yes	yes	yes
L3-L5	yes	yes	yes	yes

Chi-square test. If learners pose problems randomly, the proportion would be close to the proportion set in the assignments. Afterward, the difference of the proportions among assignments in the same story type is analyzed. If learners pose problems with some consideration, the proportion would reflect their thoughts.

We put emphasis on the analysis of satisfied constraints in the posed problems. If learners pose problems randomly without thinking, they would pose many meaningless problems or less meaningful problems in terms of the constraints. That is to say, they do not think about the structure of arithmetic word problems. However, if learners pose problems with some sort of consideration, the percentage of meaningful answers would be higher than meaningless answers.

5.3.4 Results

5.3.4.1 Analysis of Steps and Mistakes

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 problem-posing. Ideally, a student would only need three steps to pose a correct problem, because a problem in Monsakun consists of the arrangement of 3 simple sentence cards. Table 5-1 and Table 5-2 show average steps and mistakes of Japanese elementary school students and university students.

Table 5-3 Correlation analysis of satisfied constraints in the first attempt of posed problems by Japanese children and adults

Asg	Country	Constraint	Satisfied Constraints (%)												p-values in Chi-Sq. test with the setting
			0		1		2		3		4		5		
1-3		setting	15.67		45.00		27.33				6.00		6.00		
	JP-Kids	occurrence	3.45	**	21.55	**	17.24	*			14.66	**	43.10	**	2.70E-48 **
	JP-Adults	occurrence	5.66	**	6.29	**	3.77	**			13.84	**	70.44	**	6.52E-151 **
4-6		setting			68.33		24.44		1.11		4.44		1.67		
	JP-Kids	occurrence			29.57	**	15.65	+	11.3	**	30.43	**	13.04	**	2.70E-58 **
	JP-Adults	occurrence			22.64	**	6.29	**	8.81	**	19.50	**	42.77	**	0.00E+00 **
7-9		setting			29.67		26.00		1.00		2.33		1.00		
	JP-Kids	occurrence			12.93	**	26.72	+	4.31	+	19.83	**	19.83	**	2.29E-54 **
	JP-Adults	occurrence			3.77	**	12.58	**	0.00	ns	15.09	**	68.55	**	0.00E+00 **
10-12		setting	14.33		38.67		35.00				6.00		6.00		
	JP-Kids	occurrence	5.41	*	10.81	**	27.03	ns			29.73	**	27.03	**	1.60E-42 **
	JP-Adults	occurrence	4.40	**	15.72	**	13.21	**			5.66	ns	61.01	**	3.94E-110 **

ANOVA and Tukey-Kramer analysis are used to compare steps and mistakes between Level 1, Level 3 and Level 5. In both groups, we observed significant differences in average steps and mistakes in Level 1 compared to Level 5, as well as Level 3 compared to Level 5.

5.3.4.2 Analysis of Constraints in Level 5

The meaningfulness of a posed problem has been defined as a way to assess learners' thoughts. A posed problem is meaningful when it satisfies one or more constraints, and it is meaningless when the problem does not satisfy any constraint (Hasanah et al., 2017a). In the analysis, we categorize posed problems and examine which kind of problem students have posed.

To reiterate, there are five constraints to be satisfied to form a correct problem in Monsakun. The posed problems were categorized in terms of the number of satisfied constraints, then the difference between the occurrence of satisfied constraints in students' posed problems and the possible number of satisfied constraints in the assignment settings were analyzed by a Chi-square test.

We apply Chi-square test to the counts of each number of satisfied constraints in the settings and the occurrence. If the occurrence follows the proportion of the setting, it indicates that students' problem-posing in Monsakun is just in a random way. Table 5-3 shows the proportion of satisfied constraints set in the assignment and the occurrence in Japanese kids and adults, as well as the result of correlation test. The correlation analysis results compares the system's setting combination to the first attempt occurrence combination of Japanese children and adults (%) grouped by story types: Combination (1-3), Increase (4-6), Decrease (7-9), and Comparison (10-12).

5.3.5 Consideration

From the analysis of steps and mistakes in Japanese children and adults, it is shown that the adults in average had much lower number of steps and mistakes compared to the children. Especially the number of steps are closer to the setting (three steps) in adults rather than in children. It can be concluded that the adults were able to accept Triplet structure model and pose problems accordingly in Monsakun [RQ-3a].

In both children and adult groups, there is a significant difference in the averages of steps and mistakes in Level 1 compared to Level 5, as well as Level 3 compared to Level 5. This shows that, in both groups, Level 5 was more challenging than Level 1 and Level 3, in other words, both of them faced similar difficulties in Level 5.

The correlation analysis of the satisfied constraints shows a significant difference between the occurrence and settings in all the assignments ($p<.05$). This shows that both Japanese children and adults pose problems not in a random way. We find that both of them posed problems by satisfying as many constraints as possible, because the ratio of subjects has posed problems satisfying constraints less than two is lower than the setting and those have posed problems satisfying constraints more than three is higher than the setting [RQ-3b].

To answer the [RQ-3]: "How does Japanese adult use Monsakun compared to Japanese elementary school children?", it is shown by the analysis that both groups are not different: both of them faced similar difficulties in Level 5, and they posed problems, not in a random way, but tried to satisfy constraints as many as possible. This result shows that, like Japanese children, Monsakun can also be acceptable for Japanese adult as a basis to think about arithmetic word problems.

5.4 Investigation of Monsakun Use in Multiple Languages

In this section, we investigate the following research questions by experimental use of Monsakun in English and Indonesian language.

[RQ-4a] How do Indonesian and English foreign students pose problems in Monsakun?

[RQ-4b] Is Triplet Structure Model acceptable in Indonesian and English language?

5.4.1 Participants

The second part of this study aims to analyze learners' problem-posing in other languages to find out whether Monsakun structure depends on Japanese language or not. In this part, non-native Japanese university students took part in the experiment using Monsakun in English or Indonesia. 37 students used it in English and 35 students used it in Indonesian. There is no overlap between the two groups. Participants of Monsakun in English were international students from USA, Europe, Asia, and Africa region who were studying at a Japanese university and have sufficient English comprehension ability. Participants of Monsakun in Indonesia were Indonesian nationalities who were studying at a Japanese university.

5.4.2 Materials and Procedures

Participants used Monsakun Tablet for learning problem-posing of one-stop addition and subtraction in their respected languages (English, or Indonesian). The software was firstly developed in Japanese. Conversion to English and Indonesian was done with a consultation to native speakers of the languages and elementary school mathematics teacher of respected languages, to ensure that the context stays intact and the translated sentences conform to different mathematical sentence structure in different languages. As shown in Figure 5-1, Monsakun in English and Indonesian do not include any Japanese and do not require Japanese literacy.

In the experiment, the university students are firstly given the explanation about the software, and then they posed problems in a given time. After software use, participants of Monsakun English and Indonesia responded to eight 6-point Likert scale questionnaire of Monsakun use (Table 5-7). The questionnaire was adapted from the report of practical use in Japanese elementary school by Yamamoto et al (2012). A free writing section was included at the end of the questionnaire for participants to share their thoughts about the software and give advice or critics for improvement.

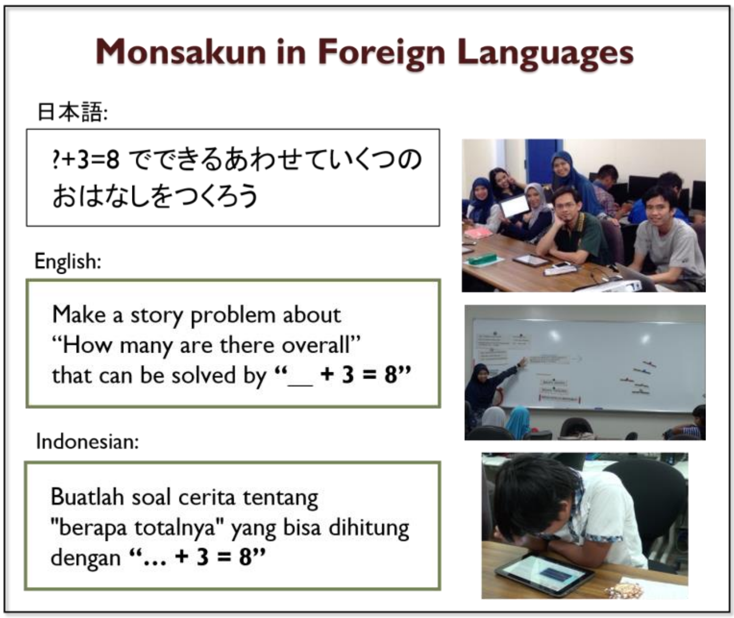


Figure 5-1 Monsakun assignment in English and Indonesian languages

5.4.3 Design and Analysis

Similar to the first part of this study, the log data from Level 1, Level 3, and Level 5 were investigated. The average of steps and mistakes were analyzed, followed by the correlation analysis of the satisfied constraints occurred in subjects' posed problems compared to the system settings. The questionnaire is analyzed to find out foreign students' subjective reception of problem posing using Monsakun. As mentioned in Introduction, the previous studies show that Monsakun is accepted by Japanese (Hirashima et al., 2007; Kurayama & Hirashima, 2010). Here, we investigate whether Monsakun is accepted by non-Japanese native adults by the log data as the objective data and the questionnaire as the subjective data.

5.4.4 Results

5.4.4.1 Analysis of Steps and Mistakes

For the international subjects group, we similarly observed the average steps and mistakes in each level. Table 5-4 and Table 5-5 shows average steps and mistakes of JP, EN, and IND subjects. ANOVA and Tukey-Kramer analysis are used to compare steps and mistakes between Level 1, Level 3 and Level 5 in each language.

5.4.4.2 Analysis of Constraints in Level 5

The analysis of satisfied constraints in Japanese, English and Indonesian subjects are shown in Table 5-6. Chi-square test is conducted between each group of subjects' answers to the system's possible combination of cards. The correlation analysis shows the result of system setting combination compared to the first attempt occurrence combination of Japanese, English and Indonesian adults (%) grouped by story types: Combination (1-3), Increase (4-6), Decrease (7-9), and Comparison (10-12).

Table 5-4 Analysis of average steps and mistakes in multiple languages (ANOVA)

	M (SD)	*Level 1*	*Level 3*	*Level 5*	*p*	*sig*
STEPS	JP	5.51 (2.53)	4.24 (1.11)	7.93 (3.39)	1.61E-11	**
	EN	5.15 (2.15)	5.54 (1.82)	14.09 (9.24)	3.42E-11	**
	IND	5.32 (2.15)	7.45 (3.68)	18.83 (11.98)	4.12E-12	**
MISTAKES	JP	0.33 (0.38)	0.18 (0.18)	0.79 (0.63)	5.09E-11	**
	EN	0.28 (0.40)	0.36 (0.31)	1.73 (1.78)	1.50E-08	**
	IND	0.34 (0.35)	0.76 (0.60)	2.59 (2.34)	1.24E-09	**

Table 5-5 Analysis of average steps and mistakes in multiple languages (Tukey-Kramer)

	STEPS			MISTAKES		
sig	JP	EN	IND	JP	EN	IND
L1-L3	no	no	no	yes	no	no
L1-L5	yes	yes	yes	yes	yes	yes
L3-L5	yes	yes	yes	yes	yes	yes

Table 5-6 Correlation analysis of satisfied constraints in the first attempt of posed problems in Japanese, Indonesian, and English

Asg	Country	Constraint	Satisfied Constraints (%)												p-values in Chi-Sq. test with the setting	
			0		1		2		3		4		5			
1-3		setting	15.7		45.0		27.3				6.0		6.0			
	JP	occurrence	5.7	**	6.3	**	3.8	**			13.8	**	70.4	**	6.5E-151	**
	IND	occurrence	5.6	**	9.5	**	7.1	**			11.1	+	66.7	**	6.8E-96	**
	EN	occurrence	6.3	**	13.5	**	4.8	**			4.8	ns	70.6	**	1.6E-104	**
4-6		setting			68.3		24.4		1.1		4.4		1.7			
	JP	occurrence			22.6	**	6.3	**	8.8	**	19.5	**	42.8	**	0.0E+00	**
	IND	occurrence			26.2	**	10.3	**	10.3	**	16.7	**	36.5	**	1.5E-167	**
	EN	occurrence			21.4	**	9.5	**	13.5	**	23.0	**	32.5	**	3.1E-159	**
7-9		setting			49.4		43.3		1.7		3.9		1.7			
	JP	occurrence			3.8	**	12.6	**	0.0	ns	15.1	**	68.6	**	0.0E+00	**
	IND	occurrence			7.1	**	38.1	ns	0.0	ns	17.5	**	37.3	**	7.4E-163	**
	EN	occurrence			8.7	**	11.9	**	2.4	ns	9.5	*	67.5	**	0.0E+00	**
10-12		setting	14.3		38.7		35.0				6.0		6.0			
	JP	occurrence	4.4	**	15.7	**	13.2	**			5.7	ns	61.0	**	3.9E-110	**
	IND	occurrence	2.4	**	7.1	**	21.4	**			21.4	**	47.6	**	6.1E-62	**
	EN	occurrence	4.0	**	11.1	**	9.5	**			23.8	**	51.6	**	1.5E-70	**

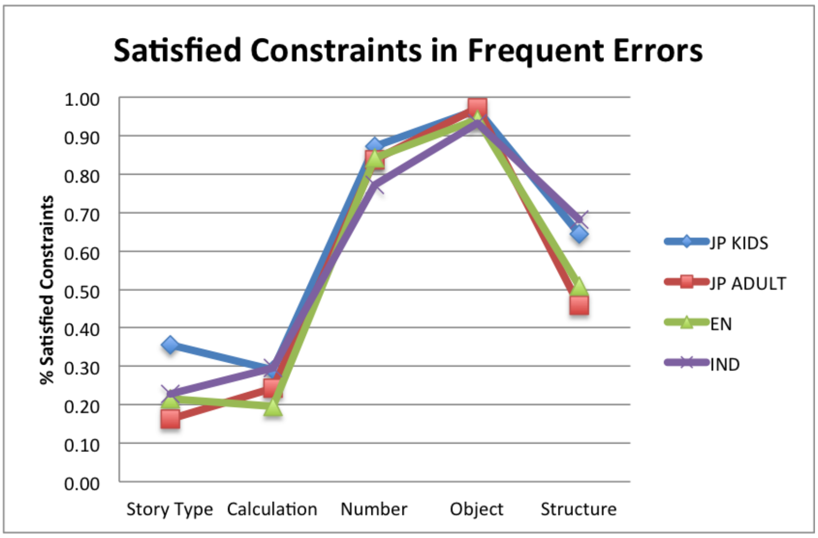


Figure 5-2 Satisfied Constraints in Frequent Error Combination

5.4.4.3 Satisfied Constraints in Frequent Errors

We have previously explained meaningful and meaningless errors related to the constraints they satisfied. In the next analysis, the frequent errors from each group of subjects were identified and analyzed regarding what type of constraint that subjects were trying to satisfy even though they made wrong problems. The result is shown in Figure 5-2. It is concluded that regardless of subjects' age and nationality, subjects had a similar line of thoughts to satisfy certain constraints when they posed a problem in Monsakun. While they found small difficulty to satisfy number and object constraints, the structure, story type, and calculation constraints were a struggle for them. Especially since Level 5 provides reverse thinking problems where the answer formula is not given directly to the learner (unlike the previous levels), subjects' difficulty in calculation constraint can be observed from this analysis.

5.4.4.4 Questionnaire Result

Table 5-7 shows the questionnaire items and Figure 5-3 shows the result of Monsakun experience use for English subjects (n=37) and Indonesian subjects (n=35). The left part of the graph shows negative responses (weakly disagree, disagree, strongly disagree), while the right part shows positive responses (weakly agree, agree, strongly agree).

We observe similar responses from both English and Indonesian subjects. Most subjects agree that posing arithmetic word problems on Monsakun are enjoyable (Q1), however, it is not easy to pose word problems (Q2). They also agree that posing problems are useful for arithmetic (Q3, Q4). While they thought that Monsakun is fairly easy to use (Q5), the assignments need some effort to understand (Q6), but the feedbacks are understandable (Q7). They also expressed interests to take part in classes with problem-posing activities (Q8).

5.4.5 Considerations

The result shows, in each language, there are significant differences in the averages of steps and mistakes in Level 1 compared to Level 5, as well as Level 3 compared to Level 5 by ANOVA and Tukey-Kramer analysis. This is similar to the Japanese children and adults, which means all groups similarly find difficulties in Level 5 [RQ-4a].

Table 5-7 Questionnaire of Monsakun experience for Indonesian and English subjects

	QUESTIONNAIRE
Q1	I enjoy posing arithmetic word problems
Q2	Arithmetic word problems are easy to pose
Q3	Posing problems is a good learning method for arithmetics
Q4	Learning to pose problems make it easier to solve problems
Q5	Monsakun is easy to use
Q6	Monsakun assignments and sentences are easy to understand
Q7	Monsakun feedbacks are easy to understand
Q8	I would like to attend arithmetic classes where problem-posing is used

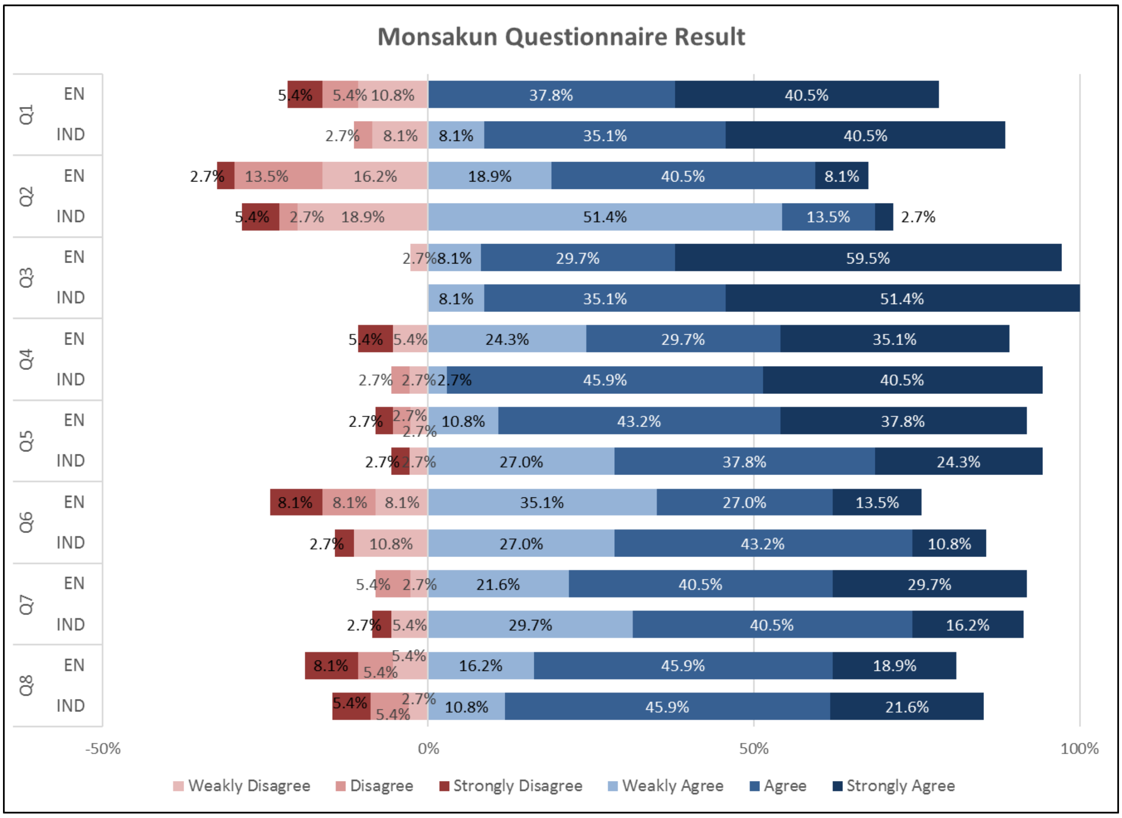


Figure 5-3 Questionnaire result of Monsakun experience by Indonesian and English subjects (%)

The result of Chi-square test showed a significant difference in assignments grouped by story types ($p < 0.05$), which implied English and Indonesian group did not also pose problems randomly. The ratio of subjects has posed problems satisfying constraints less than two is lower than the setting, and those have posed problems satisfying constraints more than three is higher than the setting.

Similar responses were observed in the questionnaire results from both English and Indonesian subjects. Most of them agreed that it is enjoyable to pose word problems on Monsakun, although posing them is not easy. They also expressed interests to take part in classes with problem posing activities. From the analysis and questionnaire result, it can be inferred that Triplet Structure Model is acceptable in foreign languages [RQ-4b].

To answer [RQ-4] "Is Monsakun use acceptable in languages other than Japanese?", we showed that all groups find similar difficulties in Level 5 and they also tried to satisfy constraints as many as possible when posing problems using Monsakun in English or Indonesian in common with Japanese children and adults.

5.5 Summary

In this study, we conducted and analyzed the utilization of Monsakun in multiple languages in order to validate the language independency of triplet structure model [RQ-3][RQ-4]. We analyzed the use of Monsakun in English or Indonesian by non-native Japanese adults and compared it with the use of Japanese children and adults. All subjects were able to complete all assignments in Monsakun. It was observed that the difficulty experienced by the learners are similar, and they tried to satisfy as many constraints as possible when pose problems. This result shows that Triplet Structure Model has potential to be acceptable for people use languages other than Japanese and to contribute to learning arithmetic word problems.

In the previous study, we have investigated Japanese elementary school students learning output of Monsakun problem-posing assignment (Hasanah et al., 2015a; Hasanah et al., 2017a). The analysis result suggested that the learners are observant of the arithmetic word problems structure and constraints. When posing problems, learners tried to satisfy the constraints as many as possible. The result served as evidence of Monsakun effectiveness in learning by problem posing in early school grade. This study conducted the experiments with four groups of subjects: Japanese elementary school students, Japanese university students, non-native Japanese university students who can speak English, and native Indonesian university students.

The Japanese university students were able to pose word problems accordingly during the experimental use, thus it is inferred that they accepted Triplet structure model [RQ-3a]. From the analysis of Japanese university students (adults) and elementary school students (children), the tendency of problem-posing is not different between Japanese children and adults. The Japanese adults were investigated in similar ways to Japanese elementary school students. Our hypothesis was, regardless of age and language, learners experienced similar thought when posing arithmetical word problem using Monsakun. The result shows that both groups experienced the same difficulty, mostly in Level 5. Furthermore, the tendency when posing problems, that is to satisfy constraints as many as possible, were found in both Japanese children and adults [RQ-3b].

Compared to Japanese, there is no significant difference in problem-posing with Monsakun in English or Indonesian. We analyzed the learning output of non-native Japanese students using Monsakun in English or Indonesian. In the experiment, all subjects were able to complete all assignment in Monsakun. Analysis result shows similar characteristics in Japanese, English and Indonesian subjects' performance [RQ-4a]. The results showed that they underwent similar tendency in posing problems. The analysis of adults speaking Japanese, English and Indonesian is essential since our assumption relates to how the children groups from the respected languages would conduct their learning using Monsakun.

We infer that through posing problem with Monsakun, regardless of age and language, subjects show some understanding of the structure of arithmetic word problem. They acquired it based on not to pose problems randomly, since the proportion of constraint satisfaction in the occurrence of subjects answers were significantly different from the one in the setting in assignments. Subjects also tried to satisfy as many constraints as possible, which shows in the frequent answers. Based on the results of data analysis and questionnaire, we suggest that the triplet structure model is acceptable in multiple languages [RQ-4b].

CHAPTER 6

INVESTIGATION OF PROBLEM-POSING LEARNING ENVIRONMENT FOR INDONESIAN ELEMENTARY SCHOOL STUDENTS

Summary: Previous studies has reported the use of Monsakun learning environment for problem-posing in actual Japanese elementary school classrooms and its effectiveness has been confirmed. As a follow-up of the previous research, in this study, ten Indonesian elementary school students living in Japan participated in a learning session of problem posing using Monsakun in Indonesian language. We introduced them to problem-posing through sentence-integration based on the Triplet-structure model and analyzed their learning activities using Monsakun. It is shown that Indonesian elementary school students were able to interact with the structure of simple word problem using this learning environment. The results of data analysis and questionnaire suggested that the use of Monsakun provides a way of creating an interactive and fun environment for learning by problem posing for Indonesian elementary school students.

6.1 Introduction

There are abundant room for improvements in Mathematics classroom in Indonesia to encourage more creative thinking and active involvement from students. Math teachers usually conduct a classroom by explaining the learning material in detail, such as providing formulas and examples of problems. Example problems are largely solved by teachers themselves and the students simply imitate the way to solve problems just like what the teacher did. A survey of 130 primary school teachers in Indonesia showed that 56.1% of them never ask students to create their own questions (Siswono et al., 2008). Interview with 27 middle school teachers disclosed that they believed the mathematical procedure needed to solve a problem should be given explicitly (Wijaya, 2015), which leave no room for creative thinking.

Researches have shown that problem posing activities positively influences students' ability to solve mathematical problems and provide an opportunity to look deeper into students' understanding of mathematical concepts and processes (Christou et al., 2005; English, 2003). Researches of problem posing in Indonesia have reported students' increased creativity, where they were able to create their own problem using new information or change from present problem (Widana, 2013). Students had increased motivation and active performance in classroom (Sumarni, 2008) and learning completeness percentage (Mubarotin, 2011). There was significant difference between learning result from students using problem posing method and conventional method (Sari, 2013). In a study of 40 elementary teachers implementing problem solving – posing based learning model, students became active learners by creating and challenging problems (Siswono, 2015).

As a follow-up of the previous research, in this study, we introduced a learning environment for posing arithmetic word problem to Indonesian elementary school students. The learning environment require students to create problems instead of solving it, and to distinguish between necessary and extraneous information in the process of creating problem. By providing a learning environment that encourage students' active involvement and the use of extraneous problems, it is hoped that students could gain creative thinking ability in mathematics.

To establish the position of this research in related field, we have investigated 70 literature/researches regarding problem posing in Indonesia in the past 17 years (1999-2015), including conference papers, journal papers, theses, and books. Among them, there were 15 researches in elementary school students, a small number compared to 36 in middle and high school students. Moreover, we only found 3 researches of problem posing using interactive software, all of them for middle/high school students. Thus, our contribution is to pioneer the study for the implementation of interactive learning environment for problem posing in elementary school grade.

6.2 Research Questions

This research investigates the introduction of Triplet Structure Model for arithmetic word problem and Monsakun experimental use by Indonesian elementary school children living in Japan to further address [RQ-4]: “Is Monsakun in languages other than Japanese acceptable to non-native Japanese speakers?”. With respect to the drawback of problem posing practice in Indonesian classroom as explained above and the usefulness of Monsakun practice in Japanese classroom situation, we believe that this software has a potential to provide a meaningful activity for Indonesian teachers as well as students in carrying out problem posing practice from early school grade.

We aim to contribute in the research field of interactive learning environment for arithmetic word problem in elementary school grade, which has not been explored yet in Indonesia. The use of Monsakun is hoped to encourage active behavior from the students in classroom such as asking questions and discussion, which in turn could deepen their understanding about the structure of word problem.

The research questions addressed in this study are:

[RQ-4c] Are Indonesian children able to learn problem posing with Triplet Structure Model?

[RQ-4d] How do Indonesian children accept Monsakun?

6.3 Methodology

Our target subjects were limited by the number of Indonesian population in Higashihiroshima, Japan. During the time this study was conducted, there were 19 Indonesian children (age 7-11) who attended Japanese elementary school. Among them, ten children (age 9-11) from grade 3 to 5 elementary school were selected to participate in this study. The practical use of Monsakun for Japanese elementary school students were conducted in grade 1 to 2 (age 7-8). However, for this study, higher age range of Indonesian children were chosen because they have previously studied in elementary school in Indonesia, thus they have been taught basic mathematics/arithmetic concept of addition and subtraction in Indonesian language which are the target of this study. They also have sufficient language ability to read, comprehend, and communicate in Indonesian, which is crucial in this study.

The experiment was carried out in one day and divided into four sections. Firstly, students were given an extraneous problem test which consist of 20 simple addition or subtraction word problems. Second, the researcher, under supervision of an expert, conducted a teaching activity to introduce the Triplet Structure Model. Afterwards, students were given a task to pose problems using provided simple sentences, followed by some discussion. The third section was Monsakun use (Level 1-5), with a lunch break in the middle of the session. In the last section, students filled out questionnaire regarding the overall activity.

The instruments used in this study are: (1) Extraneous problem test to measure students' arithmetic ability, (2) Analysis of Monsakun log data to find out students' problem posing performance, and (3) Questionnaire result to investigate students' acceptance of our learning model.

6.4 Results and Discussion

6.4.1 Extraneous Problem Test

The first section of this study was extraneous problem test. Students were randomly given one of two types of test consisting of 20 simple addition/subtraction word problems containing extra/superfluous information to be answered in 30 minutes. The material of the test was consulted beforehand to an Indonesian elementary school mathematics teacher as an expert in this field, and both type of the test have the same level of difficulty. Students were asked to read the sentences carefully, crossed out unnecessary sentences, write the corresponding calculation formula and the answer for the problem. An example of the test is provided in Figure 6-2(c).

Although the instruction was to cross out the extra information, not all students did it well, so a score is given if the final answer is right. The mean score for the extraneous problem test was 70.5% of 20 problems (M = 14.1, SD = 4.84). As this type of word problem is generally not included in the Indonesian textbooks, it was the first time that the students encountered this exercise, and the mean score shows they had enough ability to distinguish extraneous information in simple word problems. As a comparison, extraneous problem test performed by Japanese elementary school students in a study of Monsakun practical use (Yokoyama, 2005) resulted in mean score of 82% for high performance students (n=40) and 14% for low performance students (n=38).

6.4.2 Teaching of Problem Posing based on Triplet Structure Model

The second section was conducting teaching activity to introduce the concept of simple sentence problems based on Triplet Structure Model, four schema (story type) of arithmetic word problem, and exercise of problem posing in addition and subtraction. The teaching was necessary since according to the expert, Indonesian students in lower grade of elementary school are usually taught to solve word problems by paying attention to specific keywords such as “sum”, “total of” for addition or “less”, “decreased by” for subtraction, while the Triplet Structure Model put emphasis on the type of sentence and relation between them instead of focusing on keywords.

To begin the teaching activity, the translation from a conventional word problem to simple sentences are introduced. For example, Figure 6-1 shows combination story problem translated into three sentences. Then, two types of sentences in Triplet Structure Model, "independent quantity sentence" and "relative quantity sentence" are explained. For easier understanding to the children, we call them fact sentence and relational sentence, respectively. After that, different story problem was presented, and students were asked to construct simple sentences and identify their types. The target of this activity was to give students’ understanding that a simple word problem in our model consists of two independent quantity sentences and one relative quantity sentence. Figure 6-2(a) shows a scene of explaining the 4th story type “How many are the difference?”, or in arithmetic, called comparison problem. Similar to the teaching in Japanese elementary school using Monsakun (Yamamoto, 2013), the explanation was conducted using paper cards and whiteboard. Students were actively involved in this section by answering questions and offering opinions.

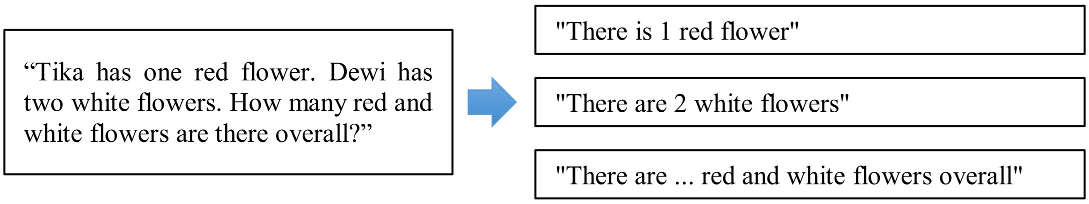
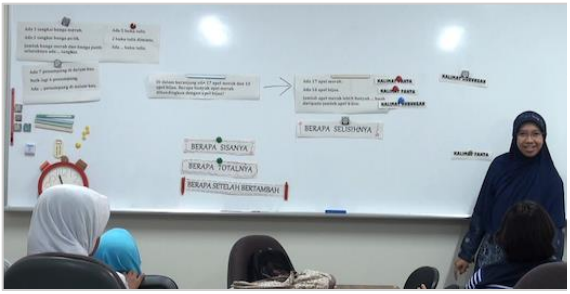


Figure 6-1 Example of translation from conventional word problem to three simple sentences.

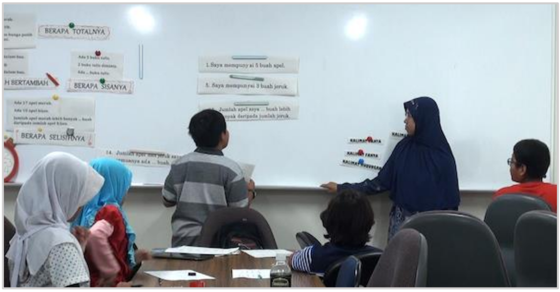
After the four story types have been explained, students were given a task to pose problems using provided simple sentences. This exercise aimed to confirm their understanding towards our model. An example of the exercise is shown in Figure 6-2(d). Fifteen sentences consist of 6 independent quantity sentences and 9 relative quantity sentences was provided. Five sentences have unknown quantity. Two objects were used throughout the sentences: apple and orange. From the sentences, it is possible to pose four types of story with multiple combination of correct problem. Students were asked to pose one of each, and random students were appointed to explain their answer in front of the class (Figure 6-2(b)). Students were also actively involved in this exercise. They discussed together why this problem is correct or wrong, or volunteered their answer when they made different problem to their friend's one.

6.4.3 Monsakun Experimental Use and Log Data Analysis

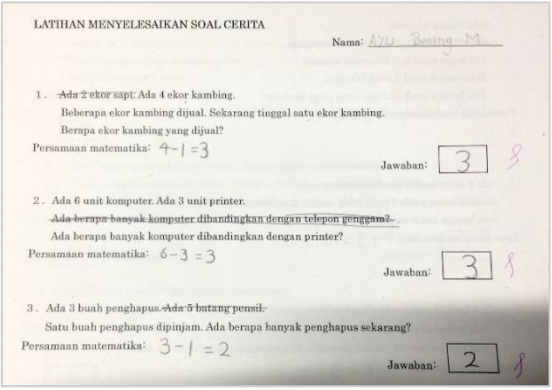
In the third section of this study, the Indonesian students used Monsakun to practice problem posing of addition and subtraction. 90 minutes total time (excluding break time) were allocated for the students to work through all assignments from Level 1 to Level 5. Scene of students experience with Monsakun are shown in Fig. 4(a). We found that students posed 2,222 problems in total, which averages in 2.46 problems per minute. Without the use of a fixed problem space system like Monsakun, it is thought that students won't be able to pose such many problem in a short time in classroom situation. Furthermore, teachers' problem of needing extra time to grade students' problem posing exercise in conventional class is solved by automatic assessment system in this learning environment.



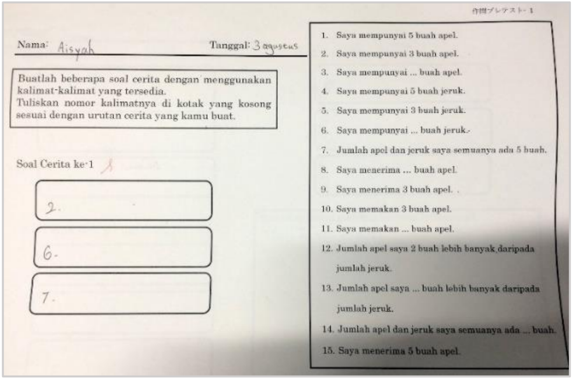
(a)



(b)



(c)



(d)

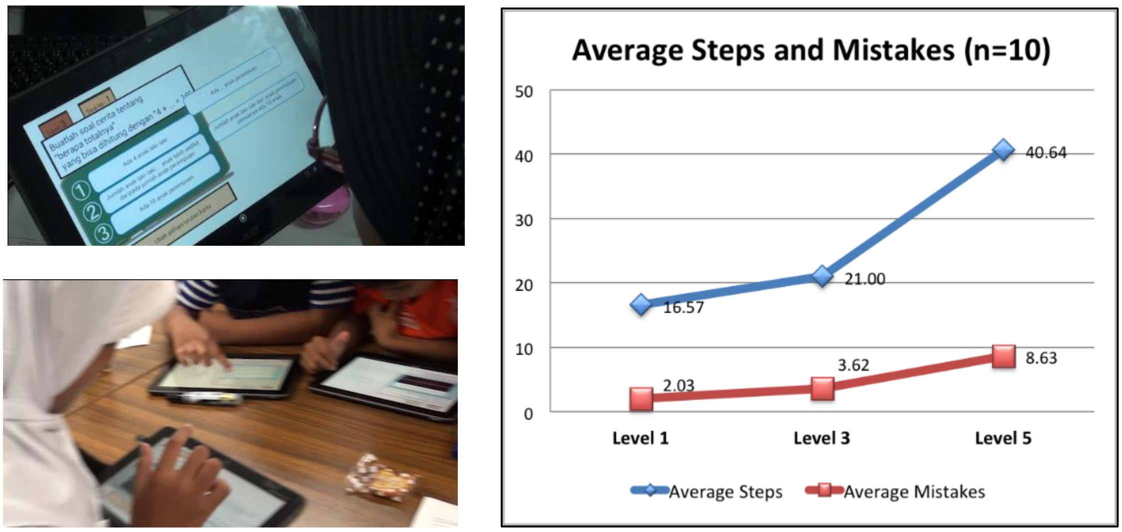
Figure 6-2 Teaching activity: introducing problem posing with sentence-integration.
(a) Scene of explaining the 4th story type "How many are the difference?".
(b) A student was invited to explain the problem he posed.
(c) Example of extraneous problem test.
(d) Example of student's answer in a task to pose problem using provided sentences (in Indonesian language).

After the experiment, the log data was analyzed and presented in Figure 6-3(b). Level 2 and 4 were omitted from the analysis because they only contain 3 assignments each, while Level 1, 3 and 5 contain 12 assignments, thus they can be observed side by side. Level 1 is the lowest level, providing forward thinking problems and story formula; Level 3 is middle level with reverse thinking problems and story formula provided; and Level 5 is the last level with reverse thinking problems and calculation formula provided.

The average steps and mistakes show increasing rate from Level 1 to Level 5, a trend also observed in previous practical use of Monsakun in Japanese elementary school students (Yamamoto et al., 2013). However, the average number is considered high compared to either of the Japanese elementary school students (Hasanah et al., 2015a).

We assume that the difference came from Indonesian students short exposure to this new learning method (one experimental session consisting 60 minutes teaching and 90 minutes system use), while the Japanese students had longer exposure (9 classroom sessions, each consisting of 35 minutes teaching and 10 minutes system use, totaling 315 minutes teaching and 90 minutes system use). Nevertheless, the Indonesian students expressed high interest during the Monsakun use and they were able to pose problems using Monsakun accordingly [RQ-4c].

The conventional teaching method in mathematics conducted one-way by the teacher rarely provides chance for students to become active learners. In contrast to this, we observed students initiating discussion among themselves or with the researcher/teacher during this section regarding the assignments and how to pose the correct problem in different story type. We believe that the use of Monsakun encourage this interaction, which in turn promote a deeper understanding about the structure of word problem. After engaged in a discussion, students were observed to be able to apply their knowledge in the next problem posing assignment.



(a) (b)

Figure 6-3 Result of Monsakun experimental use by Indonesian children
(a) Monsakun interface in Indonesian language (top) and scene of the students excitedly using Monsakun (bottom).
(b) Average steps and mistakes for assignments in Level 1, Level 3, and Level 5.

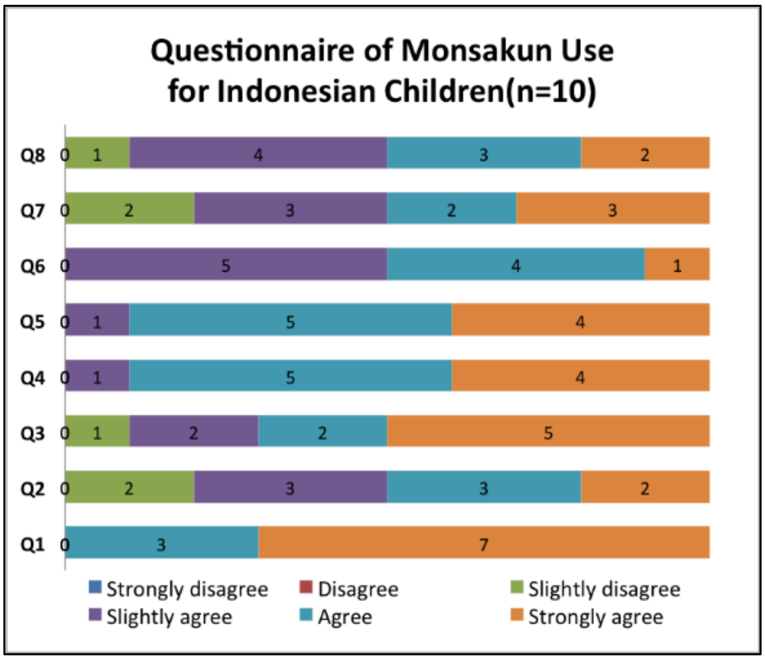


Figure 6-4 Questionnaire result of Monsakun experience by Indonesian children (1=strongly disagree, 6=strongly agree).

Table 6-1 Questionnaire of Monsakun experience by Indonesian children

No.	Questions
Q1.	Do you enjoy posing arithmetic word problems?
Q2.	Are arithmetic word problems easy to pose?
Q3.	Do you think that posing problems is a good learning method for arithmetics?
Q4.	Do you think that posing problems made it easier to solve problems?
Q5.	Do you think that it easy to use Monsakun?
Q6.	Were the assignments and sentences easy to understand?
Q7.	Were the feedbacks easy to understand?
Q8.	Would you like to attend arithmetic classes where problem posing is used?

6.4.4 Questionnaire

Figure 6-4 shows the questionnaire result of Monsakun experience use for Indonesian children (n=10). The questions are listed in Table 6-1. We observed that most students found posing arithmetic word problems are enjoyable (Q1), however, posing problems were not easy (Q2). Students thought that posing problems are useful for arithmetics (Q3, Q4). Monsakun was fairly easy to use for them (Q5), but they needed more effort to understand the assignments and feedbacks (Q6, Q7). They expressed interests to attend classes that use problem posing activities (Q8). Based on the questionnaire results, we concluded that Monsakun is acceptable and useful as problem posing learning environment for the subjects (Indonesian elementary school students) [RQ-4d].

6.5 Summary

In this study, we investigated the introduction of Triplet Structure Model for arithmetic word problem and Monsakun experimental use by Indonesian elementary school students living in Japan [RQ-4]. In the extraneous problem test, the mean score was 70.5% of 20 problems (M = 14.1, SD = 4.84). Using Monsakun, students were able to pose word problems in the rate of 2.46 problems per minute. The average steps and mistakes shows increasing rate from Level 1 to Level 5, a trend which was also observed in previous practical use of Monsakun by Japanese elementary school students [RQ-4c]. The questionnaire result shows that even though they thought it's relatively not easy to pose problems, all students enjoyed posing problems with Monsakun. The results of data analysis and questionnaire suggested that the use of Monsakun provides a way of creating an interactive and fun environment for learning by problem posing for Indonesian elementary school students [RQ-4d].

CHAPTER 7

CONCLUSION AND FUTURE WORKS

7.1 Summary of Studies

Problem posing practice involves the generation of new problems in addition to solving pre-formulated problems. However, achieving practical implementation of learning by problem posing faces the issue of inefficiency due to the time needed for assessment and giving feedback to students' posed problems. Monsakun (means "Problem-posing Boy" in Japanese) is a computer-based learning environment to realize learning by problem-posing in a practical way for one operation of addition and subtraction using sentence-integration. The integration process of solving arithmetic word problem involves processing the linguistic meaning into arithmetical formulas which are similar in any language.

The first aim of this thesis is to analyze the posed problems by university students as well as elementary school students on Monsakun in terms of whether Monsakun encourages learners to think about the structure of arithmetic word problems. The second aim of this thesis is to utilize the Triplet-structure model in multiple languages as an initial research towards suggesting a universal sentence-integration method to learn problem-posing in arithmetical word problems. Based on the research goals, we defined the main research questions as follows:

[RQ-1] Do learners pose problems in Monsakun with a consideration towards the sentence structure?

[RQ-2] In what way the trends of posed problems by learners could be explained with the Triplet Structure Model?

[RQ-3] How does Japanese adult pose problems in Monsakun compare to Japanese elementary school children?

[RQ-4] Is Monsakun in languages other than Japanese acceptable to non-native Japanese speakers?

To address these questions, we conducted researches presented in previous chapters. Figure 7-1 presents the connection of research questions addressed in each chapter towards the main research questions. Chapter 3 described analysis of Monsakun log data of Japanese university students' problem posing activity. Chapter 4 presented a study about Monsakun log data of Japanese elementary school students. Chapter 5 elaborated the analysis of posed problems by Japanese adults and children, as well as the experimental use of Monsakun in English and Indonesian language. Chapter 6 presented an introduction of the Triplet structure model and an experimental use of Monsakun for Indonesian elementary school students.

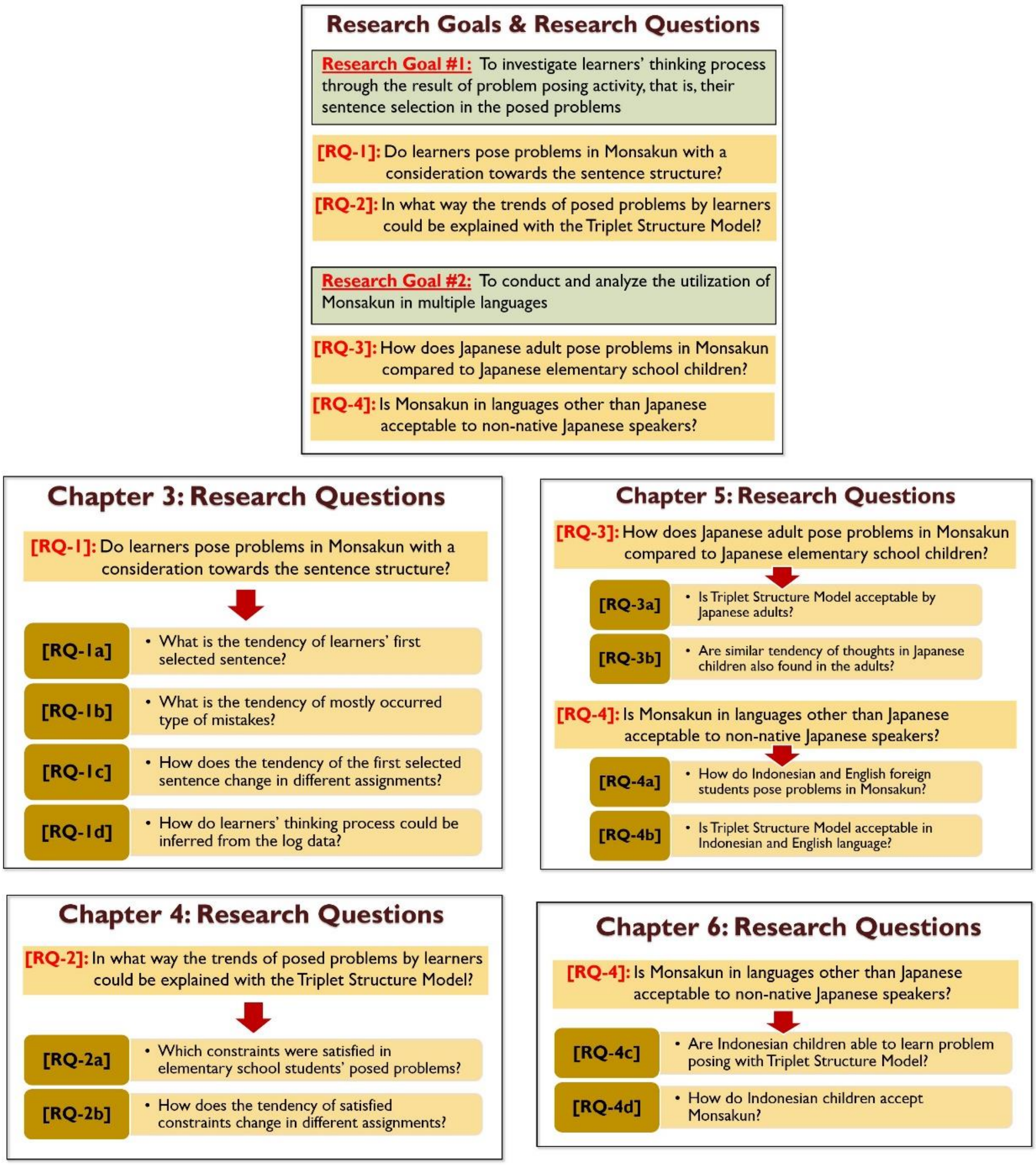


Figure 7-1 Research goals and research questions of this thesis

Chapter 3

In this research, we have conducted analysis of Monsakun log data of university students' problem posing activity to investigate whether learners pose problems in Monsakun with a consideration towards the sentence structure [RQ-1]. From the analysis, we found that the proportion of first sentence selected in each assignment were different in several ways [RQ-1a]. In every assignment, only one or two cards are significantly chosen by the learners. The proportion of each sentence card to be selected firstly is not even, although the common approach is to select the first number card. Regarding the type of mistakes, students mostly made mistake of not building correct story operation structure or confusing story operation with calculation operation structure [RQ-1b].

The next analysis regarding the tendency of the first selected sentence shows a change throughout the learning process [RQ-1c]. In forward-thinking problems (Level 1), subjects generally used a simple approach to select "first number card". However, in reverse-thinking problems (Level 5), they changed the approach to select "second number card" or "third number card". Depending on the type of story and subjects' exercise experience, they applied different approach of first card selection. From this change of approach, we infer that learners who used Monsakun were able to recognize the difference problem structure in Monsakun. The recognition of the difference is important for learners to understand the nature of arithmetic word problems. Lastly, by analyzing the frequent path taken by students in one of the problem [RQ-1d], we found out that students did not take all possible paths, but only a select few, which shows that they pose problems with some sort of thinking. The common correct path and mistake paths were able to be explained with reasonings based on our proposed model. The analysis of university students' log data served as a preliminary study towards the next chapter.

Chapter 4

In this study, we have conducted analysis of posed problems in elementary school students' problem-posing activity with Monsakun in order to investigate learner's trend of posed problems [RQ-2]. The study was conducted by testing the randomness of learners' answers and analyzes the change of tendency in the posed problems. From the analysis of satisfied constraints in frequent errors, we found that first grade students understand constraints of objects (96.3%) and numbers (85.2%), but faced difficulties in relating the numbers with the requirement of story type (40.7%) and calculation (33.3%) [RQ-2a]. Even though some learners took more steps in some assignments and pose incorrect problems, they are mostly meaningful answers because they satisfy some constraints, and many learners can get to the correct answer. We conclude that students change their thoughts to satisfy as many constraints as possible in posing problems, since the correlation analysis shows that the distribution of students' answer (actual) is different from the distribution in assignment setting (possible) [RQ-2b]. Moreover, in each story type, satisfied constraints tends to increase after they success to pose a problem in the first assignment. From the results, it can be inferred that the learners are aware of the structure and constraints of arithmetic word problems (either completely or incompletely) and try to satisfy the constraints in posing word problems with Monsakun.

Chapter 5

In this study, we conducted and analyzed the utilization of Monsakun in multiple languages in order to validate the language independency of triplet structure model [RQ-3][RQ-4]. We analyzed the use of Monsakun in English or Indonesian by non-native Japanese adults and compared it with the use of Japanese children and adults. All subjects were able to complete all assignments in Monsakun. It was observed that the difficulty experienced by the learners are similar, and they tried to satisfy as many constraints as possible when pose problems. This result shows that Triplet Structure Model has potential to be acceptable for people use languages other than Japanese and to contribute to learning arithmetic word problems.

The Japanese university students were able to pose word problems accordingly during the experimental use, thus it is inferred that they accepted Triplet structure model [RQ-3a]. The Japanese adults were investigated in similar ways to Japanese elementary school students. The tendency when posing problems, that is to satisfy constraints as many as possible, were found in both Japanese children and adults [RQ-3b].

We analyzed the learning output of non-native Japanese students using Monsakun in English or Indonesian. In the experiment, all subjects were able to complete all assignment in Monsakun. Analysis result shows that compared to Japanese, there is no significant difference in problem-posing with Monsakun in English or Indonesian, and similar characteristics were found in Japanese, English and Indonesian subjects' performance [RQ-4a]. Subjects tried to satisfy as many constraints as possible, which shows in the frequent answers. Based on the results of data analysis and questionnaire, we suggest that the triplet structure model is acceptable in multiple languages [RQ-4b].

Chapter 6

As a follow-up of the previous research, in this study, we investigated the introduction of Triplet Structure Model for arithmetic word problem and Monsakun experimental use by Indonesian elementary school students living in Japan [RQ-4]. In the extraneous problem test, the mean score was 70.5% of 20 problems (M = 14.1, SD = 4.84). Using Monsakun, students were able to pose word problems in the rate of 2.46 problems per minute. The average steps and mistakes shows increasing rate from Level 1 to Level 5, a trend which was also observed in previous practical use of Monsakun by Japanese elementary school students [RQ-4c]. The questionnaire result shows that even though they thought it's relatively not easy to pose problems, all students enjoyed posing problems with Monsakun. The results of data analysis and questionnaire suggested that the use of Monsakun provides a way of creating an interactive and fun environment for learning by problem posing for Indonesian elementary school students [RQ-4d].

7.2 Future Works

In the first part of this thesis, we analyzed learners' thinking process in problem-posing activity with the focus of frequent errors, satisfied constraints, and consider their path of choice with regards of Triplet structure-model. A limitation of this study is that it does not account for how learners think in problem posing, that is, the reason of learners' choice of steps when they arranged sentence cards to make problem, made an error, and then adjusted their selection. The analytical methods used in this study focused on the result of thinking as posed problems and the overall trends of learners' product of problem posing. As the first step of analysis of problem posing as sentence integration, the result of product analysis of the first selected sentence shows a trend that learners try to satisfy as many problem constraints as they could when posing a problem. In addition to the product analysis, the process analysis of problem posing will provide much more information about learners' thinking toward learning support. A future direction of this study will be the use of sequential analysis towards the problem posing process to understand learners' thinking and to provide assistive support in their learning activity. Furthermore, the change of tendency in learners' answers throughout their experience of posing problem has been confirmed in this research by analyzing learners' first selected sentence. An investigation of learners' full answer will be beneficial to further confirm whether their change of thinking are following the design of the Triplet structure model.

In the second part of this thesis, our aim was to investigate whether the Triplet structure-model depends on Japanese language or whether it is applicable in other languages as well. The limitation in this study are the small number of subjects and the short investigation/observation time. Ideally, the proposal of a new learning system is preferably done in multiple sessions spread in several weeks, including statistically measurable pre-test and post-test. However, we hope that this research will encourage others to continue, verify, expand, or apply it for further improvement. As the future studies, implementation and analysis of Monsakun practical use for elementary school students in various countries outside Japan is the most direct suggestion. A more in-depth analysis of students thinking while posing problems, especially in reverse-thinking problems is another suggestion to further this study.

In the subject of launching the learning environment for problem posing globally, concern was raised regarding the understanding of the target learners towards the meaning of words specifically used in Monsakun assignments. Insufficient understanding of the natural language or different interpretation of some words could occur, and in turn could affect the error rate and their success in learning with this environment. Therefore, an evaluation of learners' understanding of the natural language is a promising subject for future studies.

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APPENDIX

A. Assignments and Sentence Cards in Level 1, 3, and 5 in Monsakun English and Indonesian

LEVEL 1

No.	Assignments		Sentence Cards			
			Correct Cards		Dummy Cards	
	English	Indonesian	English	Indonesian	English	Indonesian
1	Make a word problem about "How many are there overall" that can be solved by "12 + 4 = __".	Buatlah soal cerita tentang "berapa totalnya" yang bisa dihitung dengan "12 + 4 = ..."	There are 12 red flowers	Ada 12 tangkai bunga merah	There are _ red flowers	Ada ... tangkai bunga merah
			There are 4 yellow flowers	Ada 4 tangkai bunga kuning	There are 12 red flowers and yellow flowers altogether	Bunga merah dan bunga kuning semuanya ada 12 tangkai
			There are _ red flowers and yellow flowers altogether	Bunga merah dan bunga kuning semuanya berjumlah ... tangkai	There are 12 white flowers	Ada 12 tangkai bunga putih
2	Make a word problem about "How many are there overall" that can be solved by "3 + 5 = __".	Buatlah soal cerita tentang "berapa totalnya" yang bisa dihitung dengan "3 + 5 = ..."	There are 3 yellow balloons	Ada 3 balon kuning	There are _ blue balloons	Ada ... balon biru
			There are 5 blue balloons	Ada 5 balon biru	There are 5 yellow balloons and blue balloons altogether	Balon kuning dan balon biru semuanya ada 5 balon
			There is a total of _ yellow balloons and blue balloons	Balon kuning dan balon biru semuanya berjumlah ... balon	There are 3 red balloons	Ada 3 balon merah

3	Make a word problem about "How many are there overall" that can be solved by "4 + 5 = __".	Buatlah soal cerita tentang "berapa totalnya" yang bisa dihitung dengan "4 + 5 = ..."	There are 4 boys	Ada empat anak laki-laki	There are _ boys	Ada ... anak laki-laki
			There are 5 girls	Ada lima anak perempuan	There are 4 more boys than girls	Jumlah anak laki-laki 4 anak lebih banyak daripada jumlah anak perempuan
			There are _ boys and girls altogether	Anak laki-laki dan anak perempuan semuanya berjumlah ... orang		
4	Make a word problem about "How many are there after increased" that can be solved by "2 + 3 = __".	Buatlah soal cerita tentang "berapa setelah bertambah" yang bisa dihitung dengan "2 + 3 = ..."	There are 2 cars	Ada 2 buah mobil	There are 3 cars	Ada 3 buah mobil
			There are 3 more cars	Mobil bertambah 3 buah	There are _ more cars	Mobil bertambah ... buah
			There are _ cars	Ada ... buah mobil		
5	Make a word problem about "How many are there after increased" that can be solved by "17 + 2 = __".	Buatlah soal cerita tentang "berapa setelah bertambah" yang bisa dihitung dengan "17 + 2 = ..."	There are 17 tulips blooming	Ada 17 tangkai bunga tulip yang mekar	There are 2 tulips blooming	Ada 2 tangkai bunga tulip yang mekar
			2 more tulips are blooming	Ada 2 tangkai lagi bunga tulip yang mekar	_ more tulips are blooming	Ada ... tangkai lagi bunga tulip yang mekar
			There are _ tulips blooming	Ada ... tangkai bunga tulip yang mekar		
6	Make a word problem about "How many are there after increased" that can be solved by "4 + 8 = __".	Buatlah soal cerita tentang "berapa setelah bertambah" yang bisa dihitung dengan "4 + 8 = ..."	I have 4 cards	Saya mempunyai 4 lembar kartu	I have 8 cards	Saya mempunyai 8 lembar kartu
			I receive 8 more cards	Saya menerima 8 lembar kartu	I give away 4 cards	Saya memberikan 4 lembar kartu
			I have _ cards	Saya mempunyai ... lembar kartu		
7	Make a word problem about "How many are left" that can be solved by "10 - 8 = __".	Buatlah soal cerita tentang "berapa sisanya" yang bisa dihitung dengan "10 - 8 = ..."	There are 10 eggs	Ada 10 butir telur	There are 8 eggs	Ada 8 butir telur
			8 eggs are used	8 butir telur dipakai	10 eggs are used	10 butir telur dipakai
			There are _ eggs	Ada ... butir telur		
8	Make a word problem about "How many are left" that can be solved by "13 - 9 = __".	Buatlah soal cerita tentang "berapa sisanya" yang bisa dihitung dengan "13 - 9 = ..."	I have 13 cakes	Saya mempunyai 13 buah kue	I have 9 cakes	Saya mempunyai 9 buah kue
			I give away 9 cakes	Saya memberikan 9 buah kue	I give away 13 cakes	Saya memberikan 13 buah kue
			I have _ cakes	Saya mempunyai ... buah kue		

9	Make a word problem about "How many are left" that can be solved by "10 - 4 = __".	Buatlah soal cerita tentang "berapa sisanya" yang bisa dihitung dengan "10 - 4 = ..."	There are 10 flower pots	Ada 10 pot bunga	There are 4 flower pots	Ada 4 pot bunga
			4 flower pots are taken home	4 pot bunga dibawa pulang	_ flower pots are taken home	... pot bunga dibawa pulang
			There are _ flower pots	Ada ... pot bunga		
10	Make a word problem about "How many are the difference" that can be solved by "14 - 7 = __".	Buatlah soal cerita tentang "berapa selisihnya" yang bisa dihitung dengan "14 - 7 = ..."	There are 7 girls	Ada 7 anak perempuan	There are _ boys	Ada ... anak laki-laki
			There are 14 boys	Ada 14 anak laki-laki	There are 14 more boys than girls	Jumlah anak laki-laki 14 anak lebih banyak daripada jumlah anak perempuan
			There are _ more boys than girls	Jumlah anak laki-laki ... anak lebih banyak daripada jumlah anak perempuan		
11	Make a word problem about "How many are the difference" that can be solved by "7 - 6 = __".	Buatlah soal cerita tentang "berapa selisihnya" yang bisa dihitung dengan "7 - 6 = ..."	There are 6 cakes	Ada 6 buah kue	There are _ plates	Ada ... buah piring
			There are 7 plates	Ada 7 buah piring	There are 7 less cakes than plates	Jumlah kue 7 buah lebih sedikit daripada jumlah piring
			There are _ less cakes than plates	Jumlah kue ... buah lebih sedikit daripada jumlah piring	There are 7 forks	Ada 7 buah garpu
12	Make a word problem about "How many are the difference" that can be solved by "11 - 9 = __".	Buatlah soal cerita tentang "berapa selisihnya" yang bisa dihitung dengan "11 - 9 = ..."	There are 11 envelopes	Ada 11 lembar amplop	There are _ envelopes	Ada ... lembar amplop
			There are 9 cards	Ada 9 lembar kartu	There are 11 envelopes and cards in total	Jumlah amplop dan kartu semuanya ada 11 lembar
			There are _ more envelopes than cards	Jumlah amplop ... lembar lebih banyak daripada jumlah kartu	There are 11 pens	Ada 11 buah pulpen

LEVEL 3

No.	Assignments		Sentence Cards			
			Correct Cards		Dummy Cards	
	English	Indonesian	English	Indonesian	English	Indonesian
1	Make a word problem about "How many are there overall" that can be solved by "4 + __ = 10".	Buatlah soal cerita tentang "berapa totalnya" yang bisa dihitung dengan "4 + ... = 10"	There are 4 boys	Ada 4 anak laki-laki	There are 10 girls	Ada 10 anak perempuan
			There are _ girls	Ada ... anak perempuan	There are _ less boys than girls	Jumlah anak laki-laki ... anak lebih sedikit daripada jumlah anak perempuan
			There is a total of 10 boys and girls	Jumlah anak laki-laki dan anak perempuan semuanya ada 10 anak		
2	Make a word problem about "How many are there overall" that can be solved by "2 + __ = 7".	Buatlah soal cerita tentang "berapa totalnya" yang bisa dihitung dengan "2 + ... = 7"	There are 2 yellow butterflies	Ada 2 ekor kupu-kupu kuning	There are 7 yellow butterflies	Ada 7 ekor kupu-kupu kuning
			There are _ white butterflies	Ada ... ekor kupu-kupu putih	There are 2 more yellow butterflies than white butterflies	Jumlah kupu-kupu kuning 2 ekor lebih banyak daripada jumlah kupu-kupu putih
			There are 7 yellow and white butterflies altogether	Jumlah kupu-kupu kuning dan kupu-kupu putih semuanya ada 7 ekor	There are 2 black butterflies	Ada 2 ekor kupu-kupu hitam
3	Make a word problem about "How many are there overall" that can be solved by "3 + __ = 12".	Buatlah soal cerita tentang "berapa totalnya" yang bisa dihitung dengan "3 + ... = 12"	There are 3 aluminium cans	Ada 3 kaleng alumunium	There are 12 steel cans	Ada 12 kaleng besi
			There are _ steel cans	Ada ... kaleng besi	There are _ aluminium and steel cans altogether	Jumlah kaleng alumunium dan besi semuanya ada ... buah
			There are 12 aluminium and steel cans altogether	Jumlah kaleng alumunium dan besi semuanya ada 12	There are 3 bins	Ada 3 botol kaca
4	Make a word problem about "How many are there after increased" that can be solved by "4 + __ = 15".	Buatlah soal cerita tentang "berapa setelah bertambah" yang bisa dihitung dengan "4 + ... = 15"	There are 4 kids playing	Ada 4 anak yang sedang bermain	There are _ kids playing	Ada ... anak yang sedang bermain
			_ more kids come	... anak datang untuk ikut bermain	4 kids go home	4 anak pulang ke rumah
			There are 15 kids playing	Ada 15 anak yang sedang bermain		

5	Make a word problem about "How many are there after increased" that can be solved by "__ + 8 = 14".	Buatlah soal cerita tentang "berapa setelah bertambah" yang bisa dihitung dengan "... + 8 = 14"	I have _ stickers	Saya mempunyai ... lembar stiker	I have 8 stickers	Saya mempunyai 8 lembar stiker
			I receive 8 stickers	Saya menerima 8 lembar stiker	I give away _ stickers	Saya memberikan ... lembar stiker
			I have 14 stickers	Saya mempunyai 14 lembar stiker		
6	Make a word problem about "How many are there after increased" that can be solved by "__ + 5 = 12".	Buatlah soal cerita tentang "berapa setelah bertambah" yang bisa dihitung dengan "... + 5 = 12"	There are _ boats at the port	Ada ... kapal di pelabuhan	There are 5 boats at the port	Ada 5 kapal di pelabuhan
			5 boats come back to the port	5 kapal pulang dari berlayar	12 boats come back to the port	12 kapal pulang dari berlayar
			There are 12 boats at the port	Ada 12 kapal di pelabuhan		
7	Make a word problem about "How many are left" that can be solved by "__ - 5 = 13".	Buatlah soal cerita tentang "berapa sisanya" yang bisa dihitung dengan "... - 5 = 13"	I have _ candies	Saya mempunyai ... permen	I have 5 candies	Saya mempunyai 5 permen
			I eat 5 candies	Saya memakan 5 permen	I receive 13 candies	Saya menerima 13 permen
			I have 13 candies	Saya mempunyai 13 permen		
8	Make a word problem about "How many are left" that can be solved by "__ - 5 = 14".	Buatlah soal cerita tentang "berapa sisanya" yang bisa dihitung dengan "... - 5 = 14"	There are _ kids playing	Ada ... anak yang sedang bermain	There are 5 kids playing	Ada 5 anak yang sedang bermain
			5 kids go home	5 anak pulang ke rumah	14 more kids come	Datang lagi 14 anak
			There are 14 kids playing	Ada 14 anak yang sedang bermain		
9	Make a word problem about "How many are left" that can be solved by "15 - __ = 5".	Buatlah soal cerita tentang "berapa sisanya" yang bisa dihitung dengan "15 - ... = 5"	There are 15 cars	Ada 15 mobil	There are _ cars	Ada ... mobil
			_ cars drive away	... mobil pergi	15 cars drive away	15 mobil pergi
			There are 5 cars	Ada 5 mobil		
10	Make a word problem about "How many are the difference" that can be solved by "15 - __ = 4".	Buatlah soal cerita tentang "berapa selisihnya" yang bisa dihitung dengan "15 - ... = 4"	There are 15 cats	Ada 15 ekor kucing	There are 4 cats	Ada 4 ekor kucing
			There are _ dogs	Ada ... ekor anjing	There are 15 cats and dogs altogether	Jumlah kucing dan anjing semuanya ada 15 ekor
			There are 4 more cats than dogs	Jumlah kucing 4 ekor lebih banyak daripada jumlah anjing	There are 15 rabbits	Ada 15 ekor kelinci

11	Make a word problem about "How many are the difference" that can be solved by "15 - __ = 9".	Buatlah soal cerita tentang "berapa selisihnya" yang bisa dihitung dengan "15 - ... = 9"	There were 15 guests yesterday	Kemarin ada 15 orang tamu	There were 9 guests yesterday	Kemarin ada 9 orang tamu
			There are _ guests today	Hari ini ada ... orang tamu	There are 15 guests in total of yesterday and today	Jumlah tamu hari ini dan kemarin semuanya ada 15 orang
			There are 9 less guests today than yesterday	Jumlah tamu hari ini lebih sedikit 9 orang daripada kemarin		
12	Make a word problem about "How many are the difference" that can be solved by "__ - 8 = 4".	Buatlah soal cerita tentang "berapa selisihnya" yang bisa dihitung dengan "... - 8 = 4"	There are 8 red morning glories	Ada 8 tangkai bunga merah	There are 8 white morning glories	Ada 8 tangkai bunga putih
			There are _ white morning glories	Ada ... tangkai bunga putih	There are _ red morning glories	Ada ... tangkai bunga merah
			There are 4 more white morning glories than red morning glories	Jumlah bunga putih 4 tangkai lebih banyak daripada jumlah bunga merah	There are 8 blue morning glories	Ada 8 tangkai bunga biru

LEVEL 5

No.	Assignments			Sentence Cards			
				Correct Cards		Dummy Cards	
	English	Indonesian		English	Indonesian	English	Indonesian
1	Make a word problem about "How many are there overall" that can be solved by "8 - 3".	Buatlah soal cerita tentang "berapa totalnya" yang bisa dihitung dengan "8 - 3"		There are 3 white rabbits	Ada 3 ekor kelinci putih	There are 8 white rabbits	Ada 8 ekor kelinci putih
				There are _ black rabbits	Ada ... ekor kelinci hitam	There are 3 more white rabbits than black rabbits	Jumlah kelinci putih 3 ekor lebih banyak daripada jumlah kelinci hitam
				There are 8 white rabbits and black rabbits altogether	Jumlah kelinci putih dan hitam semuanya ada 8 ekor	There are 3 brown rabbits	Ada 3 ekor kelinci cokelat
2	Make a word problem about "How many are there overall" that can be solved by "12 - 8".	Buatlah soal cerita tentang "berapa totalnya" yang bisa dihitung dengan "12 - 8"		I make _ white flower arrangements	Saya membuat ... karangan bunga putih	I make 12 white flower arrangements	Saya membuat 12 karangan bunga putih
				I make 8 red flower arrangements	Saya membuat 8 karangan bunga merah	I make _ white and red flower arrangements altogether	Jumlah karangan bunga putih dan merah yang saya buat semuanya ada ... buah
				I make 12 white and red flower arrangements altogether	Jumlah karangan bunga putih dan merah yang saya buat semuanya ada 12 buah	I make 8 yellow flower arrangements	Saya membuat 8 karangan bunga kunin
3	Make a word problem about "How many are there overall" that can be solved by "8 - 6".	Buatlah soal cerita tentang "berapa totalnya" yang bisa dihitung dengan "8 - 6"		There are 6 boys playing	Ada 6 anak laki-laki yang sedang bermain	There are 8 boys playing	Ada 8 anak laki-laki yang sedang bermain
				There are _ girls playing	Ada ... anak perempuan yang sedang bermain	There are 6 more boys than girls	Jumlah anak laki-laki 6 orang lebih banyak daripada jumlah anak perempuan
				There are 8 boys and girls playing altogether	Jumlah anak laki-laki dan perempuan yang sedang bermain semuanya ada 8 anak		
4	Make a word problem about "How many are there after increased" that can be solved by "12 - 8".	Buatlah soal cerita tentang "berapa setelah bertambah" yang bisa dihitung dengan "12 - 8"		There are _ sparrows	Ada ... ekor burung gagak	There are 8 sparrows	Ada 8 ekor burung gagak
				8 more sparrows come	Burung gagak bertambah 8 ekor	_ sparrows fly away	... ekor burung gagak terbang pergi
				There are 12 sparrows	Ada 12 ekor burung gagak		

5	Make a word problem about "How many are there after increased" that can be solved by "11 - 9".	Buatlah soal cerita tentang "berapa setelah bertambah" yang bisa dihitung dengan "11 - 9"	There are _ kids	Ada ... anak	There are 9 kids	Ada 9 anak
			9 more kids come	Datang lagi 9 anak	11 more kids come	Datang lagi 11 anak
			There are 11 kids	Ada 11 anak		
6	Make a word problem about "How many are there after increased" that can be solved by "10 - 2".	Buatlah soal cerita tentang "berapa setelah bertambah" yang bisa dihitung dengan "10 - 2"	I have 2 goldfish	Saya mempunyai 2 ekor ikan mas	I have _ goldfish	Saya mempunyai ... ekor ikan mas
			I receive _ more goldfish	Saya menerima ... ekor ikan mas	I give away 2 goldfish	Saya memberikan 2 ekor ikan mas
			I have 10 goldfish	Saya mempunyai 10 ekor ikan mas		
7	Make a word problem about "How many are left" that can be solved by "6 + 4".	Buatlah soal cerita tentang "berapa sisanya" yang bisa dihitung dengan "6 + 4"	I have _ bottles of juice	Saya mempunyai ... kotak jus	I have 6 bottles of juice	Saya mempunyai 6 kotak jus
			I give away 6 bottles of juice	Saya memberikan 6 kotak jus	I buy 4 more bottles of juice	Saya membeli 4 kotak jus
			I have 4 bottles of juice	Saya mempunyai 4 kotak jus		
8	Make a word problem about "How many are left" that can be solved by "8 + 6".	Buatlah soal cerita tentang "berapa sisanya" yang bisa dihitung dengan "8 + 6"	There are _ strawberry cakes	Ada ... kue stroberi	There are 8 strawberry cakes	Ada 8 kue stroberi
			8 strawberry cakes are sold	8 kue stroberi dijual	_ strawberry cakes are sold	... kue stroberi terjual
			There are 6 strawberry cakes	Ada 6 kue stroberi		
9	Make a word problem about "How many are left" that can be solved by "8 + 1".	Buatlah soal cerita tentang "berapa sisanya" yang bisa dihitung dengan "8 + 1"	I have _ pencils	Saya mempunyai ... batang pensil	I have 1 pencil	Saya mempunyai 1 batang pensil
			I give away 1 pencil	Saya memberikan 1 batang pensil	I buy 8 more pencils	Saya membeli 8 batang pensil
			I have 8 pencils	Saya mempunyai 8 batang pensil		

10	Make a word problem about "How many are the difference" that can be solved by "12 - 5".	Buatlah soal cerita tentang "berapa selisihnya" yang bisa dihitung dengan "12 - 5"	There are 12 guests coming today	Hari ini ada 12 orang tamu yang datang	There are 5 guests coming today	Hari ini ada 5 orang tamu yang datang
			There were _ guests coming yesterday	Kemarin ada ... orang tamu yang datang	There are 12 guests coming in total of today and yesterday	Jumlah tamu yang datang kemarin dan hari ini semuanya ada 12 orang
			There were 5 less guests coming yesterday than today	Jumlah tamu yang datang kemarin 5 orang lebih sedikit daripada hari ini		
11	Make a word problem about "How many are the difference" that can be solved by "14 - 6".	Buatlah soal cerita tentang "berapa selisihnya" yang bisa dihitung dengan "14 - 6"	There are 14 yellow flowers	Ada 14 tangkai bunga kuning yang mekar	There are _ yellow flowers	Ada ... tangkai bunga kuning yang mekar
			There are _ white flowers	Ada ... tangkai bunga putih yang mekar	There are 14 white flowers	Ada 14 tangkai bunga putih yang mekar
			There are 6 less white flowers than yellow flowers	Jumlah bunga putih yang mekar 4 tangkai lebih sedikit daripada jumlah bunga kuning	There are 14 red flowers	Ada 14 tangkai bunga merah yang mekar
12	Make a word problem about "How many are the difference" that can be solved by "9 + 4".	Buatlah soal cerita tentang "berapa selisihnya" yang bisa dihitung dengan "9 + 4"	There are 9 language exercises	Ada 9 soal bahasa	There are 4 arithmetics exercises	Ada 4 soal matematika
			There are _ arithmetic exercises	Ada ... soal matematika	There are _ arithmetics and english exercises altogether	Jumlah soal matematika dan soal bahasa semuanya ada ... soal
			There are 4 more arithmetic exercises than language exercises	Jumlah soal matematika 4 soal lebih banyak daripada jumlah soal bahasa	There are 9 science exercises	Ada 9 soal sains