Liu, C.-C. et al. (Eds.) (2014). Proceedings of the 22nd International Conference on Computers in Education. Japan: Asia-Pacific Society for Computers in Education

Schema Formulation with Schema Priming Test in Elementary Arithmetic Class in Japan

Kazuhisa SETA[a*], Akira SHIMAZOE[a*], Kanetaka MORI[b*], and Masahiko OKAMOTO[b*]
[a]*Graduate School of Science, Osaka Prefecture University, Japan*
[a]*Graduate School of Humanities and Social Sciences, Osaka Prefecture University, Japan*
*seta@mi.s.osakafu-u.ac.jp

Abstract: In this research, we implemented a system for measuring schema formulation on mobile terminals, making it easy to use in ordinary classrooms. We operated this system in an elementary school over an extended period of one month. The results showed that operating the system (1) was useful for schema formulation in students, particularly if they were weak in arithmetic, and (2) helped teachers understand students' level of comprehension, suggesting that it could help in teaching according to level of comprehension. This article gives an overview of the system developed and reports on the results of operation in the elementary school.

Keywords: Schema, Long-term Use, Mobile Terminal, Elementary Arithmetic, Operational Model

1. Educational Systems Supporting Educational Practice

1.1 Practical use of Educational Support System in the Classroom

Recently, as research advances, various educational support systems have been developed and embedded into real classroom environments, from the elementary to higher education. For example, "Monsa-kun" is an environment supporting problem posing in arithmetic, which has been reported to improve basic capabilities of problem-solving for children having difficulty with word problems in mathematics (Hirashima, Yokoyama, Okamoto and Takeuchi 2006, Yamamoto, Kanbe, Yoshida, Maeda and Hirashima, 2013). In secondary education, learning support systems such as EBS (Horiguchi, Imai, Tomoto and Hirashima, 2007) have been proposed using advanced information technologies, and in higher education, cases of research have reported on self-directed learning in a hyper space (Kashihara and Akiyama 2013, Ota and Kashihara 2010, Jouault and Seta 2014), and on training logical thinking and meta-cognitive skills in presentations (Okamoto, Watanabe and Kashihara 2013, Shibata, Kashihara and Hasegawa 2013, Kojiri and Iwashita 2013, Seta, Cui, Ikeda, Matsuda and Okamoto 2013, Seta, Noguchi and Ikeda 2011).

Looking at these learning-support systems from an information technology perspective, when they are aimed at relatively advanced post-secondary students, they tend assume computer literacy in users so they can be more advanced and incorporate more sophisticated functionality into a system.

From this perspective, current research on learning support systems can be categorized according to emphasis on (1) establishing the advance in learning support function from an information technology perspective, together with the proposed new learning method that accompanies it, or (2) eliminating learning difficulties actually encountered by children, as with Monsa-kun.

For the learning support systems in category (1) it tends to be difficult to set a common curriculum in the universities and colleges where they are used, and the computer systems developed tend to assume use in a limited range of scenarios. They have not proposed '*operational models*' that anticipate expansion into many educational scenarios, because they require, for example a specialized computing environment. Conversely, learning support systems that focus on solving issues in real learning environments, such as Monsa-kun and the system from Deguchi (Deguchi, Yamaguchi, Funaoi and Inagaki, 2004), need to be able to be embedded into teaching scenarios with strong time constraints, as is the case in schools. This restricts the functionality that can be incorporated, but handles difficulties faced by many students, so such systems have proved to be useful.

Of course, much of the research attempts to address both aspects, (1) and (2), so it is difficult to divide all research into two clear categories, but it is unmistakable that research on learning support systems that aim to be used in a wide range of learning environments must clarify what it means for a system to be useful when introduced into real learning scenarios.

The primary goals of this research, as a research approach oriented to practical use in the classroom, are to develop Schema Priming Tests (SPT), which are an instructional support and assessment tool for resolving issues with elementary school students having difficulty solving arithmetic word problems, and to operate it for approximately one month to identify issues in embedding it into classrooms.

1.2 Using Educational Support Systems Integrated with Teaching

For the past 20 years or so, the phrase "formative assessment is the most important assessment for instruction" has been used often in Japanese schools. It refers to teaching while maintaining a continuous awareness of the students' understanding of the material. To do so, formative assessment must be taken several times within a teaching unit to understand the extent to which each student has acquired the relevant skills and where they are encountering difficulty. Knowing the learning results from each student in this way is also helpful for teachers to improve their instructions.

However, even when using integrated instruction and assessment, the main role of teachers is to teach, so they cannot spend large amounts of time carefully assessing the learning activities of individual students. With the recent spread of tablet terminals, students can have their own terminal, and the potential for providing learning support to individual students according to their progress in expanding. Considering this, one of the advantages of a learning support system using tablet terminals is as a formative assessment tool for understanding children's learning progress.

In other words, an effective way to use tablet terminals would be as a tool to assess children's understanding of the content of a unit as the unit is being taught in school.

A secondary objective of this research was to use the iPod Touch as a tablet terminal, together with Schema Priming Tests (SPT) implemented on it, integrated into teaching of a unit on area to grade five students. This was used to conduct practical research on the effectiveness of using SPT for longitudinal assessment and support of the process of schema formulation.

In Section 2 below, we discuss the reasons and process of developing SPT and in Section 3 we give an overview of the system. Section 4 gives an overview of the experimental study conducted using SPT, Section 5 discusses the effectiveness of SPT, and Section 6 summarizes the conclusions.

2. Solving Process of Word Problem and Schema

2.1 Process of Solving Arithmetic Word Problems

It is not rare for children to have difficulty with arithmetic word problems, and approximately 30% cannot solve them, regardless of whether they are able to solve calculation problems (Okamoto 1999).

The reason that word problems are found difficult is that they are composed of two processes, that of reading and understanding the word problem, and that of performing the calculation to reach to the answer. Generally, most children that cannot solve word problems are able to solve calculation problems, so of these two processes, it is less common for children to fail at performing the calculation to get the answer.

Recently, the four phases theory (Mayer 1985, Cummins, Kintsch, Reusser and Weimer, 1988) has become influential, stating that solving word problems occurs in four qualitatively different steps. These four steps are 1. Translation, 2. Integration, 3. Planning, and 4. Execution.

According to Okamoto, they consist of the following cognitive processes:

- **Translation:** Translating from a problem text into mental representation with mathematical and syntactical knowledge.

- **Integration:** Determine the problem type using schema knowledge, and integrate it with the overall problem representation.
- **Planning:** Establish a plan (equation) to achieve the goal, based on the overall problem representation.
- **Execution:** Perform the calculation using knowledge of computational algorithms to obtain the answer.

Causes for failure in solving word problems occur in the three phases before execution, and particularly in the integration phase.

The integration phase involves the process of finding relationships among the multiple sentences in the word problem and creating a situation model that is a core representation integrating the overall problem. Then, for the type of word problems with few steps done at the elementary school level, an equation can be derived directly from this situation model. In other words, mistakes made in forming an equation are seen as failures at the integration phase rather than the planning and execution phases.

2.2 Problem Schema and the Integration Phase

In the integration phase, a situation model representing an overall understanding of the problem is built, and the student's pre-existing knowledge related to the problem structure, called problem schema, plays a most important role in the integration step. For example, reading the sentence, "How fast is Akira walking?" an adult would know this is a problem related to speed, and to solve it requires other factors such as distance and time. What enables adults to do this is having solved various types of problems related to speed in the past, and having acquired a schema for speed problems, which includes the formula, distance = speed × time.

In fact, Mayer (Mayer 1985) identified various problem types among word problems that are taught in the early stages of elementary school, such as compare problems and change problems, and showed that students acquire problem schema for each problem type. Okamoto also showed that even with adults, if they did not have a clear problem schema for compare problems, they often had difficulty solving them, and that whether the problem schema is easy to use contributes strongly to problem integration.

Thus, problem schemas are strongly related to the integration step of solving word problems, and children that have formed a problem schema can more easily solve the problem. This suggests that supporting problem schema formulation in children using iPods, and providing longitudinal assessment of the level of schema formulation would be a powerful teaching support tool for teachers.

2.3 Theoretical Background for Schema Priming Tests

Schema priming tests were originally used by Okamoto as test problems and were developed as a tool for assessing the degree of schema formulation.

The basic idea is an application of the concept of semantic priming from cognitive psychology. Semantic priming is the phenomenon that processing of a target stimulus can be accelerated by presenting a stimulus that has a deep semantic relationship with the target stimulus, called the prime stimulus, before the target stimulus is presented.

In a schema priming test, a question (describing what will be required) is first presented as a prime stimulus, then the whole problem text (the target stimulus) is presented, and then the student is asked to decide semantically, whether they can solve the problem or not.

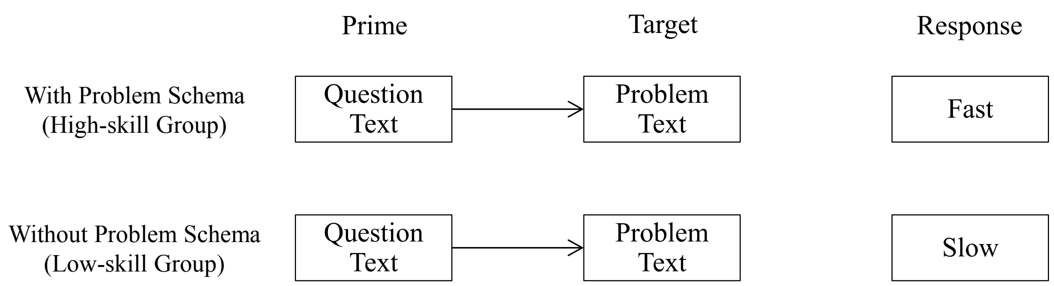

Figure 1. Relations between Schema Organization and Reaction Time

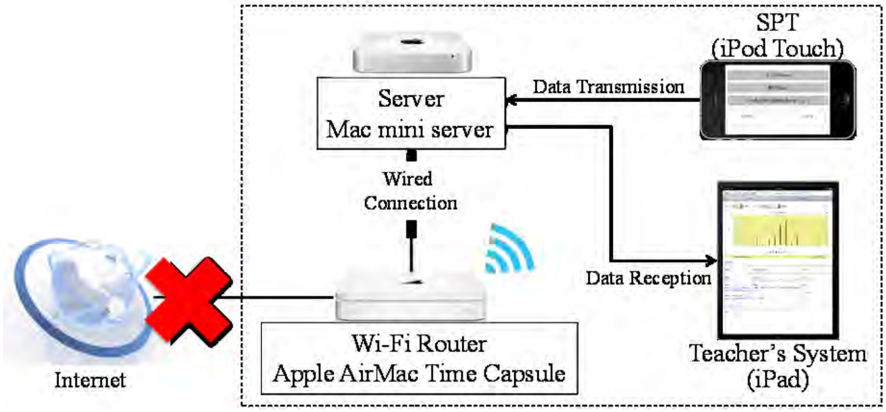

Figure 2. Structure of the System

If the student has an adequately formed schema, the response to the schema priming test will be faster, as shown in Fig. 1, so the degree of problem schema formulation can be determined by the shortening of test response times.

3. Development of Schema Priming Tests

3.1 Overall System Structure

The overall structure of the system developed in this research is shown in Fig. 2. The system adopts a client-server model built using a private network through a Wi-Fi router without Internet connection.

A Mac Mini Server is used to host a MySQL server, iPod Touch terminals are used to implement SPT on the client side, and an iPad is used to allow the teacher to see the work of the students. Building the system in this way has the following advantages:

1. There are no space constraints, such as needing to operate in a PC room, and it is easy to introduce into classes.
2. Children can operate it intuitively.
3. Due to the above, children more easily use it voluntarily outside of class.
4. The network system can easily be brought into a classroom as a package, so it is easy to use.
5. The state of students' activity is sent immediately to the teacher's system through the private network, promoting an integrated approach to teaching and assessment.

3.2 Basic Operation of the Schema Priming Test

The purpose of developing SPT was to measure students' level of understanding easily and accurately.

With SPT, a question (describing what will be requested) is first presented as the prime stimulus, then the whole word problem (the target stimulus) is presented, and then the student is asked to make the semantic decision, whether they can solve the problem or not.

According to Okamoto, students that have formed an adequate schema will be able to answer the above question quickly and correctly, and the student's degree of schema formulation can be

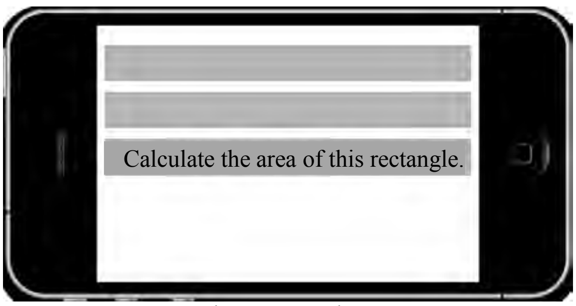

Figure 3. Prime

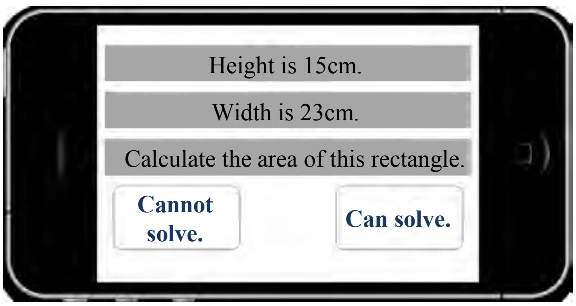

Figure 4. Target

determined from the response times and number of correct answers.

Schema knowledge is also used with conventional test problems, but what is assessed is the calculation written on the paper and the result, and the degree of schema formulation is not displayed. In contrast, the SPT developed in this research uses a question format that asks about the validity of a word problem (a format that does not necessarily require planning), so it is specialized to measure ability to understand the overall problem, in other words, schema formulation.

Specific operation of the system is described below. For each problem, the system presents (1) the question (e.g. “Calculate the area of this rectangle.” in Fig. 3), and (2) the conditions (e.g. “Height is 15cm,” “Width is 23cm.” in Fig. 4), with a delay, and then records the time from when the conditions were presented until the answer is given. Operation screens for the system developed in this research are shown in Fig. 3 and Fig. 4.

1. Question indicating what will be calculated is presented (Fig. 3: prime stimulus).
   (Still for 3 s)
2. Overall problem presented (Fig. 4: target stimulus)

4. System Operation Overview

The sequence of experimental study is shown in Fig. 5.

- **Subjects:** 77 Grade 5 students from two classes in elementary school A (38 in one group, 39 in the other).
- **Time:** Oct. 31, 2013 to Nov. 29, 2013.
- **Teaching unit:** Finding areas of rectangles (sub-unit 1), triangles and parallelograms (sub-unit 2), and trapezoids and rhomboids (sub-unit 3).
- **SPT teaching materials:** Using the above sub-units, 16 word problems for each sub-unit were prepared as SPT materials.
- **SPT operation (during class):** As study of each sub-unit was completed in class, the system was used with the applicable word problems, also in class. Note that the second group of 39 students was not able to use the SPT after completing the topic on trapezoids and rhomboids. The instructors used the system additional times beyond what they did in class time, twice for the first group, and once for the second group. 42 numbered iPod Touch terminals were used. These were brought into the classroom by the teacher, and students used the same device, selecting the class and seat number on the screen before performing the SPT.
- **SPT operation (outside of class):** To give opportunities to use SPT outside of class time, the devices were placed in the class so students could use the system freely, without placing additional burden on the teachers. However, since the number of devices was limited, they were allocated by time periods to the different classes (e.g.: group 1 during the morning, group 2 in the after noon). Mainly, they were used during two occasions given to group 1, and only a few members from group 2 used them outside of class.

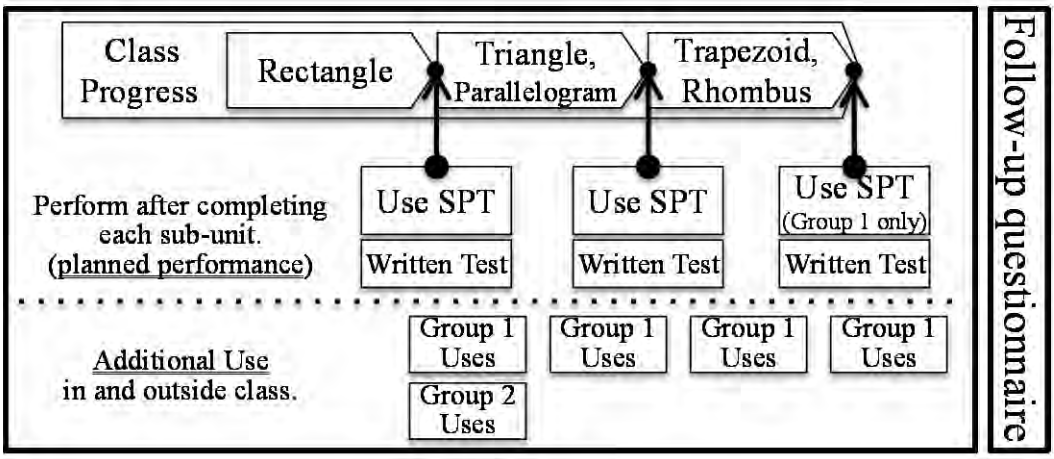

Figure 5. Flow of the Experimental Study

In addition to analyzing the level of effort, marks and response speeds for each student, the following confirmed the usefulness of operating the SPT for schema formulation.

- **Written tests:** After completing sub-units in class, the usual tests performed in school to test understanding and also written tests including extraneous problems (described below) were performed. Then, the relationships between those results and the level of effort and marks from the SPT were analyzed. These written tests consisted of four ordinary questions and four questions with extraneous information, totaling eight questions.

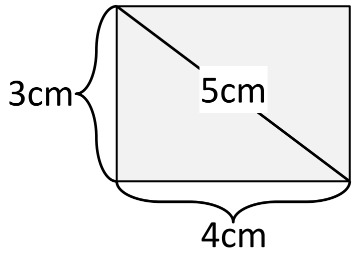

Figure 6. An Extraneous Problem

- **Teacher interviews:** Interviews were conducted with the two teachers after the experimental study, regarding the effects of the system on level of understanding, the students' involvement, and suggestions for improvement.
- **Student surveys:** A five-level survey of students was conducted after the practice, regarding system usability, ability to motivate, and effect on marks.

Extraneous problems are problems that include conditions that are not necessary to solve the problem. An example is shown in Fig. 6. Such problems require identifying the elements comprising the substance of the problem from among all of the information given and to determine what is enough information to solve it. As such, they are useful in determining the degree of schema formulation.

5. Schema Formulation and Problem Solving Performance Improvements through SPT

5.1 Schema Formulation Process through SPT

As described in Section 3, the students in group 2 were not given the opportunity to take the SPT for sub-unit 3, so we analyzed the data from the 38 students in group 1 regarding tendencies in response times.

The SPT response time trends for SPT done in the classroom after completing each of the three sub-units are shown in Fig. 7. A 2×3×2 mixed ANOVA was done on the response times, using the three-factors of frequent vs. infrequent use, sub-unit (rectangles vs. triangles and parallelograms vs. trapezoids and rhomboids), and SPT problem type (normal vs. unsolvable). The first factor is between subjects, while the other two factors are within to subjects.

In the results of the distribution analysis, frequency as a primary effect was significant ($F_{(1,36)}=6.34$, $p<0.05$). The high-frequency group had shorter response times than the low-frequency group, and children that used the system more frequently clearly were able to determine more quickly whether they could solve the problems or not. The sub-unit also had a significant effect ($F_{(2,72)}=77.07$, $p<.01$). With low-order testing using the Bonferroni method, times for triangles and parallelograms are shortest, then for trapezoids and rhomboids, and finally for rectangles. Further, a main effect of problem type ($F_{(1,36)}=60.43$, $p<.01$) and an interaction of sub-unit × problem type ($F_{(2,72)}=55.11$, $p<.01$) were significant, so in low-order testing, for rectangles, response times for solvable problems were clearly longer than for unsolvable problems.

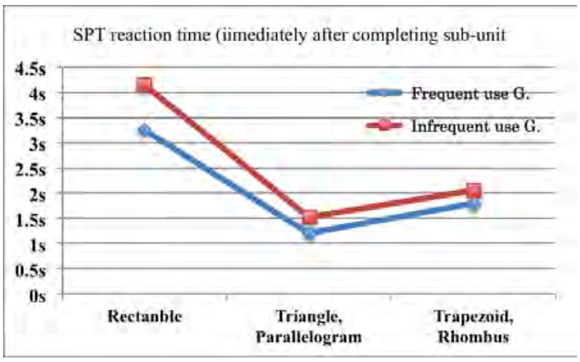

Figure 7. Mean Reaction Time of SPT in Area Unit

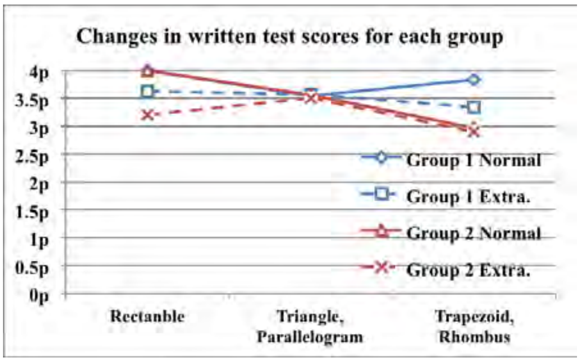

Figure 8. Mean Scores of Paper Test

Decision times were shorter for the high-frequency group, which could mean that subjects became more accustomed to using the system or that their schema formulation could have been more advanced. However, comparing the response times for sub-units, response times did not become shorter according to the number of tests, and the response times for sub-unit 2 were clearly the shortest overall to begin with. If response times became faster simply by repetitions and becoming familiar with operation of the system, then sub-unit 3 should have been the fastest, but sub-unit 2 produced the shortest decision times. This suggests that the decision time for schema priming tests is the time required to integrate the problem using schema knowledge. Considering this, the fact that the high-frequency group response times were shorter suggests that using the SPT more often promoted schema formulation.

5.2 Improvement of Problem Solving Performance through SPT

To study whether using the SPT promoted students' schema formulation requires comparison of a control group that does not use SPT, and an experimental group that does use SPT. As discussed earlier, group 2, which did not do SPT for sub-unit 3 on trapezoids and rhomboids, can be viewed as a control group. In other words, comparing group 1 with group 2 in sub-unit 3 can be considered a comparison of an experimental group with a control group. Accordingly, we did a comparative analysis of the written test results, including extraneous problems, from the two classes.

The written test scoring trends for each group are shown in Fig. 8. A 2×3×2 mixture distribution analysis was done using the three factors; class (group 1 vs. group 2), sub-unit (rectangles vs. triangles and parallelograms vs. trapezoids and rhomboids), and problem type (necessary problem vs. extraneous information problem).

As a result of the distribution analysis, the main effects that were significant were: class ($F_{(1,74)}$=4.80, p<.05), sub-unit ($F_{(2,148)}$=6.99, p<.01), class × sub-unit interaction ($F_{(2,148)}$=3.63, p<.05), problem type ($F_{(1,74)}$=17.39, p<.01), sub-unit × problem type interaction ($F_{(2,148)}$=5.70, p<.01), and class × sub-unit × problem-type interaction ($F_{(2,148)}$=3.23, p<.05).

To compare classes in more detail, we conducted lower-order testing using the Bonferroni method for class × sub-unit interaction. There was no difference in scores between classes for "rectangle" and "triangle and parallelogram", but there was a significant difference in scores for both classes for "trapezoids and rhomboids" ($F_{(1,74)}$=7.80, p<.01), and group 1, which worked with SPT, clearly had higher scores.

For the two sub-units that showed no difference between classes, both classes had used SPT, but for the sub-unit that showed a difference between classes, trapezoids and rhomboids, only group 1 used the SPT. This suggests that using the SPT promoted schema formulation, and as a result, this had the effect of raising problem solving scores.

The two classes have different teachers, so there are potential differences in their teaching technique to result in differences between the classes, but if differences in their technique alone were a cause, there should have been differences in the first and second written tests as well, but this was not observed. In other words, for both practices where SPT was used, the teachers were also teaching effectively. Based on the above consideration, we can say that using SPT continually while teaching the units effectively promotes schema formulation and problem solving itself.

5.3 Effects of SPT on Learning Processes of Children Weak in Arithmetic

Next, we examined in detail, the sort of students on which SPT has the greatest effect. We compared changes in scores for students weak in arithmetic, who regularly received attention from teachers (designated "marked students" or MS), with those of other students ("unmarked students", US). The average frequency of use for group 1, consisting of 9 MS and 29 US, was 9.8 times and 11.5 times respectively. For group 2 with 4 MS and 35 US, it was 4 times and 3.6 times respectively.

The scoring trends on paper tests for MS and US in each class are shown in Fig. 9 and Fig. 10. Comparing the test scores from MS and US in group 1 for three paper tests, showed no significant difference. In other words, when using SPT continuously while teaching, children weak in arithmetic were also able to understand the study materials adequately.

In contrast, a significant difference was observed between MS and US in group 2 ($t_{(25)}$=-5.3, p<.01). The graph shows clearly that the difference increased as learning progressed. This result shows

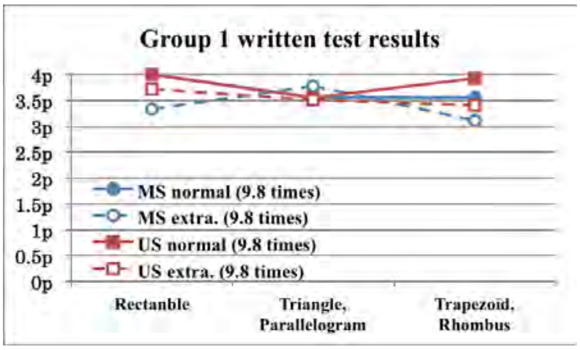

Figure 9. Mean Scores of Paper Test (US and MS in the Class1)

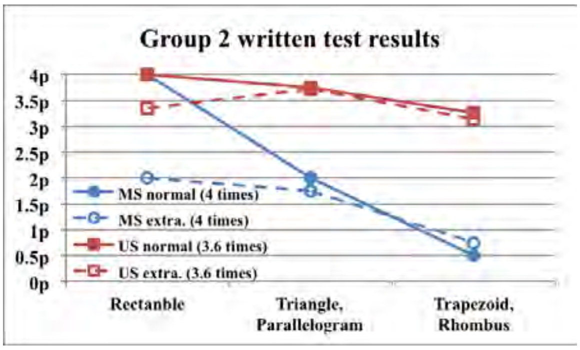

Figure 10. Mean Scores of Paper Test (US and MS in the Class2)

that in the class using SPT less frequently, children weak in arithmetic were not understanding the learning materials adequately.

The above analysis shows that using SPT is effective for schema formulation, but such results are not likely to be obtained simply by embedding the SPT. A major factor besides this could be that embedding SPT and conducting small tests for each sub-unit increases the opportunities for the teacher to understand the students' progress.

This suggests that schema formulation and improvements of teaching activities due to SPT operation result in the following synergies.

1. SPT is helpful for the teacher to know students' level of understanding, and this promotes teaching.
2. Engaging in SPT promotes schema formulation in the students. The effect on schema formulation was large for MS in particular, from the analysis of MS and US.

5.4 Results of Teacher and Student Questionnaires

We now mention the results of interviews and surveys given to teachers and students. The results of teacher interviews are summarized in Table 1.

Regarding effectiveness in motivating study, teachers felt that, judging from the students' behavior, students found the system easier to use and were less opposed to using it than to studying with text books or problem sets, and this increased motivation. The student survey results also suggested this.

A survey was conducted with items as shown in Table 2 and answers using a five-rank score (strongly agree, somewhat agree, I don't know, somewhat disagree, strongly disagree). The results are shown in Fig. 11. The overall results were quite positive.

From questions 1, 2, and 5, students used the system without difficulty, and enjoyed working with it even though the type of question in SPT was unusual: deciding whether problems were valid or not.

Questions 3 and 4 suggest that students themselves found that the system was helpful for

Table 1. Interviewing Results from 2 Teachers

Usefulness for Motivating Study	
	・ Students happily said, "I want to try, I want to try!" and were very willing. The number of students consulting with the teacher and other students increased.
	・ Frequency of system use depends on personality. Low level students showed perseverence, saying things like "I just want to get one more right!" Low level students really seemed to make progress. As not seen before, students showed overflowing confidence at the
Course practice reflecting students' level of understanding	
	・ Written tests including problems with extraneous information were a good stimulus. For example, asking "Where is the height in this figure?" has been incorporated into the class.
Introduction into classes, usage issues	
	・ Opportunities to use the teacher system in order to identify students weak in arithmetic and give them attention were few. However, it appeared to be useful for making arrangements in class based on overall trends (e.g. whether to hold a review class, or to provide personalized attention).
	・ We only allowed use under supervision by teachers, so management was difficult, and this may have been inconvenient for the children.
	・ We felt it may be more convenient to have one terminal per student.
	・ The system would have been used more if students were required to use it more.

learning, and they see this effect positively as well.

Question 6 indicated that many students would like to use SPT again in the future, suggesting that SPT materials could be expanded to include other units that students would accept, making it a more useful tool.

For question 7, regarding motivation to study arithmetic, 56% of students responded that studying arithmetic was more fun (34% for strongly agree, 22% for somewhat agree), suggesting that using the system contributes to increasing motivation to study arithmetic.

Table 2. Questionnaire Items for Students

1. Was the schema game fun?
2. Was the schema game simple?
3. Do you think you learned arithmetic in the schema game?
4. Do you think you learned to solve area problems more easily by playing the schema game?
5. Was it easy to use the schema game?
6. Do you want to play the schema game again?
7. Did it make studying arithmetic more fun?

The survey results from only MS are shown in Fig. 12. It also shows the same, mainly positive trend for MS. The analysis in 5.3 suggested that the system is useful for schema formulation in students thought to be weak in arithmetic, but for question 7 in particular, 62% of MS responded for themselves that studying arithmetic was more fun (46.1% strongly agree, 15.4% somewhat agree), so this is also a very significant result.

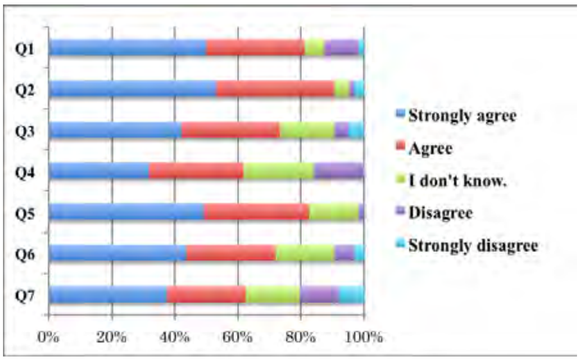

Figure 11. Questionnaire Results (US and MS)

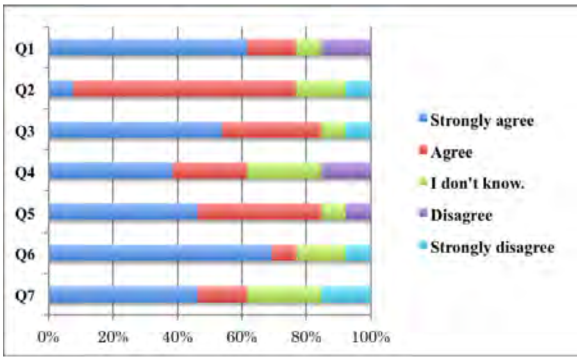

Figure 12. Questionnaire Results (MS only)

6. Concluding Remarks

This paper describes a system for assessing learners' schema formulation easily, and reports on long-term use of this system in an elementary school. The results, from the perspective of the usefulness of the developed system, are: (1) the group using the system more frequently may have had better schema formulation than the group using it less frequently, (2) differences in written test results between classes due to having done or not done the SPT were confirmed, and (3) differences in number of times used clearly produced large differences in scoring trends for MS.

We also confirmed that the system developed in this research can be used in a way that integrates with teaching when introduced into the classroom. The system also operated with stability, not going down once over an experimental study of one month. By implementing a tool that reduces difficulties faced by many students on a mobile terminal in this way, even elementary students can enjoy engaging in learning. Since it is easy to embed into classrooms, which have strong time constraints, and has been shown to be stable through real operation, it also demonstrates a possible operational model, which is another research result.

One issue with introducing and using the system in classrooms was that we could not provide enough number of terminals. We tried to compensate for this, but increasing the number of terminals should be considered to encourage more-active use of the system. On the other hand, the system was implemented on iPod Touch terminals, which are less expensive than PCs or other types of tablet terminal, so cost related difficulties are relatively small-scale with this implementation.

In elementary schools, which are classroom-based, the class teacher is aware of students requiring particular care, so in this case the teacher's system was hardly used at all. Thus, looking only at these results suggests there is not a strong need for it in the primary classroom. On the other hand, we received a comment that it may be more useful in middle and high-school, which are course-based, so we would like to evaluate usefulness of the system for teachers in secondary education.

Future issues include (1) building a process model of students' comprehension (e.g.: knowledge of a unit is not organized sufficiently because other applicable units are inadequate) through continual use of the system, and (2) developing functionality to give feedback to students based on this information.

References

Tsukasa Hirashima, Takuro Yokoyama, Masahiko Okamoto, Akira Takeuchi: A Computer-Based Environment for Learning by Problem-Posing as Sentence-Integration, ICCE2006, pp.127-130

Sho Yamamoto, Takuya Hashimoto, Takehiro Kanbe, Yuta Yoshida, Kazushige Maeda, Tsukasa Hirashima: Interactive Environment for Learning by Problem-Posing of Arithmetic Word Problems Solved by One-step Multiplication, Proc. of ICCE2013, pp.51-60, (2013)

Tomoya Horiguchi, Isao Imai, Takahito Toumoto, Tsukasa Hirashima, "A Classroom Practice of Error-based Simulation as Counterexample to Students' Misunderstanding of Mechanics", Proc. of ICCE 2007 (2007), pp.519-525, (2007)

Akihiro Kashihara and Naoto Akiyama: Learner-Created Scenario for Investigative Learning with Web Resources, Proc. of the 16th International Conference on Artificial Intelligence in Education (AIED 2013), pp. 700-703, Springer, Memphis, USA (2013).

Koichi Ota, and Akihiro Kashihara: Mining Collective Knowledge for Reconstructing Learning Resource, Proc. of ICCE 2010, Putrajaya, Malaysia, pp.104-106, (2010).

Corentin Jouault and Kazuhisa Seta: Adaptive Self-Directed Learning Support by Question Generation in a Semantic Open Learning Space, Int. J. of Knowledge and Web Intelligence, 2014, to appear

Corentin Jouault and Kazuhisa Seta: Content-Dependent Question Generation for History Learning in Semantic Open Learning Space, Proc. of 12th International Conference on Intelligent Tutoring Systems, (2014, to appear)

Ryo Okamoto, Yuto Watanabe, and Akihiro Kashihara: Review Support System with Visual-Oriented Annotation Method for Presentation Rehearsal, Proc. of the 21st International Conference on Computers in Education (ICCE2013), pp. 295-297, Bali, Indonesia, 2013

Yasuo Shibata, Akihiro Kashihara, and Shinobu Hasegawa: Skill Transfer from Learning to Creating Presentation Documents, ITHET2013 (International Conference on Information Technology Based Higer Education and Training), ISBN: 978-1-4799-0086-2, Antalya, Turkey, 2013

T. Kojiri and N. Iwashita: Visualization of Slide Relations for Supporting Presentation Speech Preparation, Proc. of the 21st International Conference on Computers in Education, pp.1-10 (2013)

Kazuhisa Seta, Liang Cui, Mitsuru Ikeda, Noriyuki Matsuda, Masahiko Okamoto: Meta-Cognitive Skill Training Program for First-Year Bachelor Students Using Thinking Process Externalization Environment, Int. J. of Knowledge and Web Intelligence, Vol. 4, No. 2, pp. 217-237, (2013)

Kazuhisa Seta, Daijiro Noguchi, Mitsuru Ikeda: Presentation-Based Collaborative Learning Support System to Facilitate Meta-Cognitively Aware Learning Communication, The Journal of Information and Systems in Education, Vol. 9, No.1, pp.3-14, (2011)

Akiko Deguchi, Etsuji Yamaguchi, Hideo Funaoi and Shigenori Inagaki: Concept Mapping Software to Reconstruct Learning Processes: Enhancement Based on the Teacher's Requests and Its Evaluation from the Viewpoint of Teachers, Proc. of ICCE 2004, pp. 935-940, (2004)

Etsuji Yamaguchi, Hideo Funaoi, Shigenori Inagaki, Akiko Deguchi, Naohisa Misawa, and Shinichi Kamiyama: Enhancement of the Digital Fortune Line System for Accelerating Mutual Examination of Learners' Conceptual Ecologies, Proc. of ICCE

Masahiko Okamoto: The Study of Metacognition in Arithmetic Word Problem Solving, Kazama-shobo Publishing Tokyo, (1999) (in Japanese)

Richard E. Mayer: "Memory for algebra story problems," Psychological Review, Vol.92, No.1 pp.109-129, 1985

Denise D. Cummins, Walter Kintsch, Kurt Reusser, Rhonda Weimer: "The role of understanding in solving word problems," Cognitive Psychology, 20, pp.405-438, 1988