A longitudinal study of mathematical word problem solving in children using a computer-based metacognitive strategy

Hidetsugu Tajika1, Narao Nakatsu2, Ewald Neumann3, Hisae Kato4, Tomoko Fujitani5, Chie Hotta6, and Hironari Nozaki2

Abstract

The purpose of the study was to examine the efficacy of self-explanation for helping elementary school children solve mathematical word problems through computer-based support over two years. Twenty fourth graders participated in the study. The students solved worked-out examples for thirty minutes once a week in six two-week training sessions. They completed a word problem test at the end of each session. The results showed that all of the students gradually solved more word problems correctly than before. We classified students in the training condition into three groups according to the patterns of their test scores. Students in the upper group, who had consistently higher scores, self-explained their solution processes using inferences. Some students in the middle group, who were gradually increasing their scores, also self-explained their solution processes using inferences. Most students in the lower group, who had consistently low scores, only took notes on the results of their past records about solution steps. Self-explanation as a metacognitive strategy is discussed.

Notes: 1 Kobe Shinwa Women’s University, Japan

2 Aichi University of Education, Japan

3 University of Canterbury, New Zealand

4 Mukogawa Women’s University, Japan

5 Hyogo University of Education. Japan

6 Kansai University of Welfare Sciences, Japan

Summary

The purpose of this study was to test the long term efficacy of self-explanation as a metacognitive strategy for elementary school students learning to solve mathematical word problems through computer-based support over two years. Recent research has shown that self-explanation is an effective metacognitive strategy across a wide range of task domains. In Tajika et al. (2007), sixth grade students self-explained each solution step to the worked-out examples of mathematical word problems using paper and pencil. The results produced clear evidence supporting the effectiveness of self-explanation. Subsequently, Tajika et al. (2012) reported similar results for mathematical word problem solving using computer-based self-explanation support with fifth graders. The present study attempts to extend the results of Tajika et al. (2012) in a longitudinal study using fourth graders.

Twenty fourth-grade students in an elementary school (13 girls and 7 boys with a mean age of 10 years 6 months when the study began) participated in the pretest. We used 36 worked-out examples in the study as the training word problems. Each example had five to nine solution steps and the answer. Half of each of the types of training word problems were easy and the other half were difficult. These worked-out examples which involved target items (correct answers) and distractor items (errors) were programmed via the Java applet. Students selected the numbers of the correct explanations (target items). Our computer-based support program for self-explanation was designed to be accessible by the Web server. At the start of the study, all of the fourth grade students received a word problem pretest. Then, the students worked with computer-based self-explanation support training. The students had six two-week training sessions up until December 2013 (i.e., February 2012, July 2012, December 2012, February 2013, July 2013, and December 2013). One week after each training session, the students received a mathematical word problem test, which incorporated worked-out examples presented on the computer. They took the mathematical word problem test for forty minutes. They also had a transfer test after the final training session. Completion of the transfer test took fifteen minutes.

According to the scores on the pretest and the mathematical word problem tests of the fourth grade, the results of the students were classified into one of three groups. Each group had six or seven students who demonstrated the typical patterns of performance on word problem tests for fourth graders. Table 1 shows the results of the students for three groups over two years. As shown in Table 1, students in the upper group (n=7) kept attaining greater gains over two years. Students in the middle group (n=7) and lower group (n=6) were also gradually improving their scores in each grade. A detailed protocol analysis showed there was a high correlation between mean numbers of correct solutions and mean scores on word problem tests, r=.78 (p<.01). Self-explanations were broken down into inferences versus repetitions and/or others based on the protocols described in their notebooks. The results showed that the number of students in the upper group who self-explained their solution processes using inferences was more than those in the other two groups.

The present study lacked an empirical control condition, in which students have no computer-based metacognitive strategy support. However, when we compared the present results and those of the control condition of Tajika et al. (2012), the present results regarding the same mathematical word tests and transfer tests were significantly better than those of the control condition of Tajika et al., despite the fact that the students were from a younger cohort. Overall, these findings suggest that many students constructed mental models required for solving mathematical word problems through the activities of self-explanation, which in turn led to enhanced performance for these students.

Table 1 Mean Proportion Correct (Ms) and Standard Deviations (SDs) for Three Groups Over Two Years

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| --- |
| Pretest Word Problem Test Transfer Test  Feb 4th Feb 4th Jul 5th Dec 5th Feb 5th Jul 6th Dec 6th Dec 6th  Group M (SD) M( SD) M(SD) M(SD) M(SD) M(SD) M(SD) M(SD)  Upper 1.00(.00) .82(.09) .74(.12) .95(.10) .87(.08) .73(.17) .62(.23) .76(.10)  Middle .91(.12)　 .84(.07) .47(.16) .79(.14) .79(.20) .47(.19) .56(.27) .62(.14)  Lower .65(.16) .73(.18) .57(.13) .65(.18) .67(.08) .36(.14) .40(.12) .71(.16) |

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