THE EFFECT OF METACOGNITIVE TRAINING ON THE MATHEMATICAL WORD PROBLEM SOLVING OF LOWER ACHIEVERS IN A COMPUTER ENVIRONMENT

Su Kwang Teong

Centre for Studies in Mathematics Education, University of Leeds

This study demonstrates that explicit metacognitive training appear to benefit lower achievers' mathematical word problem solving in a computer environment. 11 to 12-year-old Singaporean students in collaborative pairs were assigned to two word problem solving groups. The first group received explicit metacognitive training before word problem solving with WordMath (treatment); and the second group undertook word problem solving with WordMath (control). Results from the analysis of pair think aloud protocol data suggest that treatment lower achievers appeared to be more successful and elicited better regulated metacognitive decisions than control lower achievers.

INTRODUCTION

Recently, there has been much interest in training lower achievers with a metacognitive intervention strategy and observing its influence on lower achievers' mathematics (e.g. Maqsud, 1998; Cardelle-Elawar, 1995). For example, Cardelle-Elawar (1995) reports that lower achievers trained in learning to monitor and control their own cognitive processes for solving mathematics problems do better than untrained students. According to Schoenfeld (1985), compared with an 'expert' problem solver, 'novices' lack essential metacognitive monitoring, assessing and decision making skills, which are essential elements that determine one's success or failure in problem solving. This paper reports on an investigation of the effect of metacognitive training on the mathematical word problem solving of four pairs of 11 to12-year-old Singapore lower achievers in a computer learning environment. Specifically, the metacognitive training focuses on activating lower achievers' metacognitive processes when solving word problems in a WordMath (Teong, 2000, p. 25) environment. The primary aim of the investigation is to identify the role of metacognition in lower achievers' word problem solving in a computer environment.

METHODOLOGY

Eight 11 to 12-year-olds from two Singapore primary schools were involved in this intensive study over a period of eight weeks. Four lower achievers from each school, chosen according to their 1998 end-of-the-year Mathematics examination result, were assigned to two groups: a pair of lower achievers (LA) from each school had explicit metacognitive training before solving word problems with WordMath (treatment or T); and a pair of lower achievers from each school solved word problems with WordMath without metacognitive training (control or C). In each school, the lower achievers had four training sessions and the author taught each session. The training sessions consisted of a set of learning instructions, and the students worked collaboratively with WordMath word problem solving tasks. Each pair of lower achievers had two additional training sessions in which each pair solved four word problems during each training session. These additional training sessions served as practice sessions for the lower achievers to feel comfortable talking in front of the cam-corder. A posttest was administered to treatment and control lower achievers whereby the students' word problem solving using WordMath with/without metacognitive training was video-recorded and the data analysed. Six weeks later, due to time and logistic constraints, a delayed posttest was only administered to the treatment lower achievers where the students' word problem solving using WordMath was video-recorded and the data analysed.

ANALYSIS AND RESULTS

The data analysis was undertaken to try to identify the differences the types of word problem solving behaviours shown by pairs of treatment and control lower achievers while solving mathematical word problems. The following shows the analysis procedures applied to one of the eight word problem solving protocols for two pairs of lower achievers. Analysis of the MARBLE word problem has been chosen because it best illustrates the lower achievers' unique word problem solving behaviours and collaborative style. The MARBLE word problem context is as follows.

> Joe Ee, Mun Fai and Jing Hao shared 400 marbles amongst themselves. Joe Ee received 28 marbles. Jing Hao received seven times the total number of marbles Joe Ee and Mun Fai received. How many more marbles did Jing Hao receive than Mun Fai?

A modified Artzt and Armour-Thomas' framework was used to analyse the lower achievers' think aloud protocols. The original Artzt and Armour-Thomas' (1992) framework aims to highlight major strategic decisions made by a group of students. The think aloud protocol is parsed into episodes, representing periods of time during which the students are engaged in unique types of word problem solving behaviour. The original Artzt and Armour-Thomas' framework (1992) had eight episodes to partition group think aloud protocols. The author modified their framework for the purpose of analysing pair think aloud protocols. The behaviours, described in Teong (2000, p. 71-75) are: reading (cognitive); analysis (metacognitive); exploration (cognitive); exploration (metacognitive); planning (cognitive); planning (metacognitive); implementation (cognitive); implementation (metacognitive); verification (cognitive); and verification (metacognitive). The following figures, Figures 1 and 2, demonstrate the overall structure of the solution analysis for MARBLE by S1 and S2 (T/LA), and S3 and S4 (C/LA). This is followed by a display table, Table 1, which shows the time and the percentage of behaviours coded as metacognitive and cognitive for posttest and delayed posttest of the MARBLE word problem.

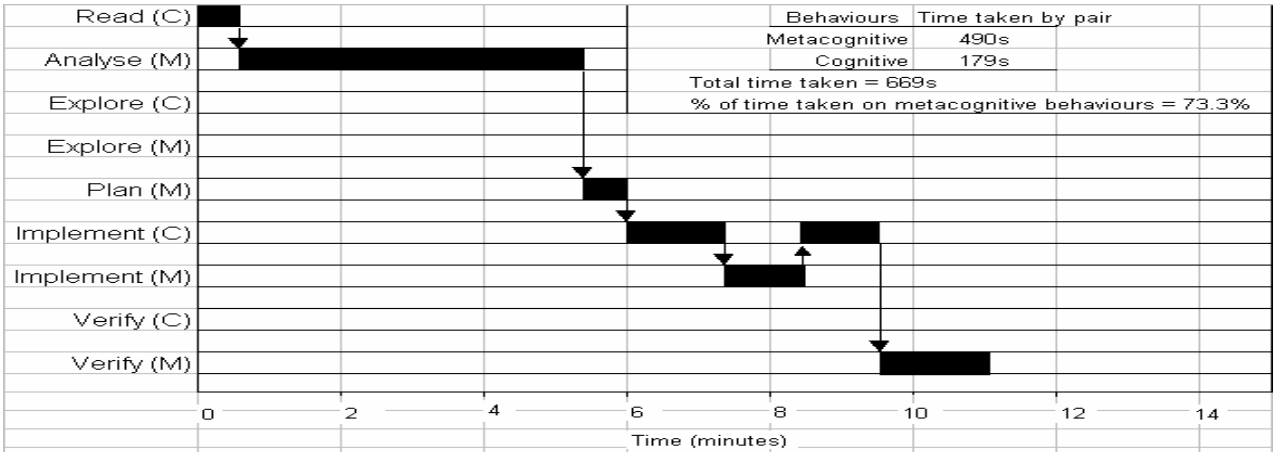

Figure 1: A timeline representation of S1 and S2 (T/LA) solving MARBLE word problem during posttest

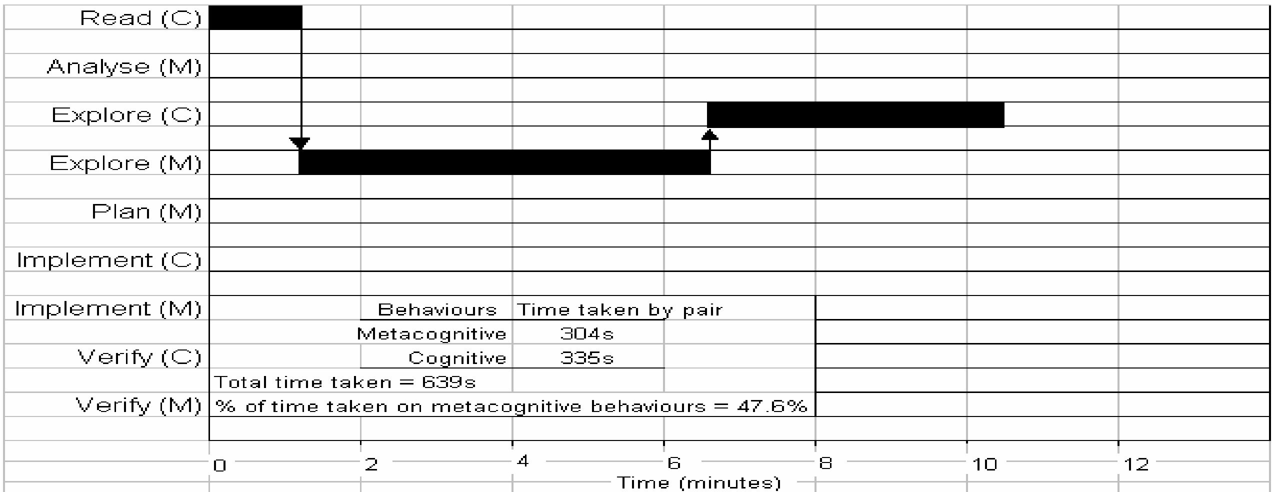

Figure 2: A timeline representation of S3 and S4 (C/LA) solving MARBLE word problem during posttest

Numerical representation of lower achievers' think aloud protocol data

The following table, Table 1, demonstrates the time two pairs of lower achievers devoted to cognitive and metacognitive behaviours during posttest and delayed posttest for the MARBLE word problem.

The results in Table 1 appear to indicate that treatment lower achievers devote more time to metacognitive behaviours compared with control students. For example, S1 and S2 (T/LA) devoted 73.3% and 95.9% of their time to metacognitive activities during posttest and delayed posttest respectively compared with S3 and S4(C/LA) who devoted 47.6% of their time to metacognitive activities during posttest.

S1 AND S2'S (T/LA) PROGRESSION OF WORD PROBLEM SOLVING ACTIVITY

The protocol for S1 and S2 (T/LA) (see Figure 1) during posttest could be summarised as an orderly progression of activity, Read → Analyse → Plan → Implement (cognitive) → Implement (metacognitive) → Implement (cognitive) → Verify (metacognitive) which led to their success in solving the word problem. They also seemed in control of their cognitive actions, as illustrated by the following exchange after the pair had drawn the diagram which represented the word problem.

S1: The question asked how many more marbles did Jing Hao receive than Mun Fai.

S2: So we have to find Mun Fai

S1: Let me see (pauses for 3 seconds). This is the unknown (pointing to the diagram)/ unknown because of Mun Fai. So let say this is one small unit /

S2: Okay

	Post test		**Delayed Post test**
Behaviour Category	**S1 and S2* (T/LA)**	**S3 and S4 (C/LA)**	**S1 and S2* (T/LA)**
Meta-cognitive	490 (73.3)	304 (47.6)	612 (95.9)
Cognitive	179 (26.8)	335 (52.4)	26 (4.1)
Total	669 (100)	639 (100)	638 (100)

* correct solution

Table 1: Time in Seconds (and %) devoted to Cognitive and Metacognitive Behaviours Per Pair for MARBLE word problem during Posttest and Delayed Posttest

These strengths contributed to their success in their entire word problem solving during posttest. With respect to the MARBLE word problem, they devoted 73.3% of their time to metacognitive activities (see Table 1).

During delayed posttest, the protocol for S1 and S2 (T/LA) could also be summarised as a well-regulated progression of activity, Read → Analyse → Plan → Implement (metacognitive) → Verify (metacognitive), which led to their success in solving all the word problems. The control of their word problem solving for MARBLE was again evidenced by the percentage of time they devoted to metacognitive activities: metacognitive (95.9%) and cognitive (4.1%) (see Table 1).

S3 AND S4'S (C/LA) PROGRESSION OF WORD PROBLEM SOLVING ACTIVITY

The protocol of S3 and S4 (C/LA) (see Figure 2) could be summarised as:

1. Reading the word problem; and
2. Exploration (cognitive), where the pair was observed to take the numbers out of the word problem context and used different operations to manipulate these numbers.

S3 and S4 appeared to have limited resources to aid them in their word problem solving. They engaged in exploration and tried making local assessments at the beginning of the word problem solving session, but their metacognitive decisions were weak and they did not help them. With respect to the MARBLE word problem, they devoted 47.6% (see Table 1) of their time to metacognitive activities. This pair was successful in 25% of their word problem solving.

DISUSSION

The above findings suggest that treatment lower achievers appear to be more successful in word problem solving compared with control lower achievers. In addition, there is evidence that treatment lower achievers are devoting more time to regulating and monitoring their word problem solving process even after a prolonged period of six weeks with metacognitive instruction (see Table 1). These findings concur with Cardelle-Elawar's (1995) study. Cardelle-Elawar found that lower achievers with explicit metacognitive training outperformed control group where students still relied more on the teacher for the right answer. Cardelle-Elawar's (1995) study suggests that metacognitive training provides a classroom structure for low achievers to think for themselves and to recognise their limitations which in turn promotes problem solving success (op cit p. 93).

The analysis of the think aloud protocol also suggests that treatment and control lower achievers responded differently when they were 'stuck'. For example, S1 and S2's (T/LA) apparent control and monitoring strategies when they were 'stuck' during posttest and delayed posttest usually led them away from inappropriate paths into paths of solution. The following exchange, while the pair was solving another word problem, illustrates how the pair's good control and monitoring strategies directed them to find alternative path of solution. S1 and S2 were exploring (metacognitive) for 179 seconds when they realised that they were 'stuck'.

S2: It doesn't match what! (3) This plus is extra right?
S1: We're just doubling/doubling it (3). So, this and this is 1 dollar extra.
S2: Hm mm
S1: But this doesn't match. This, the minus and plus sign doesn't match. So/ what we have to do is to make this minus sign become add sign/
S2: How do to do that? (17)
S1: Is that true/ that 4 kg is 4? 5 kg is 4 dollars?
S2: 5 kg is / how do you get the 4 dollars?
S1: 3 plus 1
S2: 5 kg is 4 dollars. Then why do you add together?
S1: Let me try. If 5 kg is 4 dollars, then 10 kg is 8 dollars (4)
S2: 5 kg is 4 dollars / yeah. 10 kg is 8 dollars. So, 8 dollars minus 3 because of [the 4
S1: [but why do you add the 3 dollars plus 1 dollar?
S2: because one is short and one is extra/

During the 17 seconds pause, S2 was silently referring to the word problem. When she proposed that 5 kg was 4 dollars, S1 and S2 analysed this idea with reference to the diagram they had initially drawn. S2 also checked on S1's suggestion. These good control and monitoring strategies appeared to have helped in S1 and S2's (T/LA) word problem solving success.

In sharp contrast, S3 and S4 (C/LA) appeared to engage in explore (cognitive) when they realised they were 'stuck'. For example, when S3 and S4 realised that their solution was incorrect in the episode explore (metacognitive) (see Figure 2), they did not proceed to reread the word problem nor analyse the word problem based on the diagram they had drawn earlier. Instead they continued making inappropriate assumptions with regard to the relationship between the givens and the unknowns in the word problem situation. This behaviour appeared to be consistent with lower achievers' S3 and S4 (C/LA) word problem solving.

According to Kaplan and Davidson (1988), when students reach points of impasse on word problems which are novel or require unavailable knowledge, instructional intervention offering problem solving strategies and encouraging self-reflection has been found to improve problem solving performance. Hence, there is reason to suggest that S3 and S4 (C/LA) need metacognitive training so that they will be able to discern when they have to move away from inappropriate solution paths, relocate their resources so that they might effectively solve word problems by constantly monitoring their solution paths.

CONCLUSION

This paper supports an approach to instruction which includes metacognitive training in mathematical word problem solving in a computer environment. The metacognitive training promotes lower achievers' metacognitive awareness by informing them about effective word problem solving strategies, and making them aware of their cognitive processes during word problem solving. As a result, the lower achievers seem more likely to be able to monitor and regulate their own thinking, which appears to contribute to their success in solving word problems.

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