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The Effects of Children's Metastrategic Activities on Strategies to Control Variables at a Scientific Reasoning Task

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Abstract: The purpose of this study was to examine the effects of metastrategic exercise on a scientific reasoning strategy to control variables, and investigate the developmental patterns in the strategy usage within a given period. Two groups composed of 90 fifth grade students engaged in a scientific reasoning task over six daily sessions. Additionally, one group engaged in metastrategic exercise on fictional students' strategies of controlling variables on the task, while the other spent equivalent time on an unrelated task. Based upon results of the study, the following conclusions can be drawn. First, the metacognitive exercise on the strategy to control variables has positive and long-standing effects on the strategy performance at the reasoning task. The exercise also takes effect of near-transfer. Taking into consideration only about sixty minutes of metastrategic practice, the results provide the validity of the activity in order to develop children's reasoning strategies. Second, in a scientific reasoning task, each child seems to go through one out of two developmental patterns in their usage of reasoning strategies: gradual change or fundamental change. Considering the ratio of pattern of fundamental change between the two groups, it is clear that the metacognitive exercise influences the developmental pattern of strategy usage.

Key words: metacognition, metastrategy, scientific reasoning, reasoning strategy, control of variable.

INTRODUCTION

Metacognition literally means one's cognition about cognition or thinking about one's thinking (Garner, 1994; Harris & Hodges, 1995; Osborne, 1998; Paris, Lipson, & Wixson, 1994). Although researchers in this field have defined the term in different ways, metacognition has generally been divided into two components: metacognitive knowledge and metacognitive management (Baker, 1991; Cox, 1994; Harris and Hodges, 1995; Osborne, 1998; Paris & Winograd, 1990; Sigler, 1997; Yore *et al.*, 1998). The metacognitive knowledge is about oneself, the task one faces, and the strategy one employs. The metacognitive management is the related cognitive processes in order to achieve a desired end, such as defining the cognitive task, planning, using strategies, monitoring, and evaluating. Various cognitions about cognition can be labeled 'metaperception', 'metacomprehension', 'metaconception', and 'metamemory', with 'metacognition' remaining the superordinate term (Garner, 1994). Metastrategy is also subordinate term on metacognition. Thus, metastrategy refers to knowledge individuals have of their own strategies and their ability to evaluate, monitor, and control their own strategy usage.

Since 1990s, metacognition has actively been studied by many science educators and researchers, with the augmentation of recognition that efforts to improve the science education need to be focused more on the learning side than on the teaching side (e.g., Beeth, 1998; Blank, 2000; Duit, 1991; Gunstone & Mitchell, 1997; Hennessey, 1993; Hennessey & Beeth, 1993; Vosniadou & Ioannides, 1998). These studies commonly argued or proved that metacognition is important to science teaching and learning. Despite the importance of metacognition, however, researches on this construct have been restricted to

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the investigation on its effects as instructional strategies for students' conceptual change. Now, it is needed to extend our understanding of metacognition to the more general domain of thinking and reasoning.

In the last two to three years, Kuhn and her colleagues published several interesting studies that involve metacognition in scientific reasoning, for example, studies of Andersen (1998), Kuhn & Pearsall (1998), and Pearsall (1999). As the researchers pointed out, it is clear that metacognitive competence directly and indirectly influences the development of scientific reasoning strategies. Several challenges such as followings, however, remain to be solved in their studies. First, it is needed to examine whether metacognitive exercise in a single condition is fruitful or not on students' development of reasoning strategies. One of the most important benefits of social interaction is that children are exposed to multiple interpretations of the environment and must reflect on those interpretations as well as their own in order to present a meaningful expression of their thought to the other (Andersen, 1998; Brown, 1997; Carr & Biddlecomb, 1998; Karabenick, 1996; Mason & Santi, 1994; Metz, 1995). Metz (1995) claimed as follows; "Capitalizing on social interaction within the science classroom can help children make their ideas explicit and subject them to criticism. Exploration of such ideas as theory, evidence, and hypothesis can support children's formulation and identification of their own and others' thinking" (p.108). Mason & Santi's study (1994) showed that classroom discussions would stimulate higher level reasoning. Andersen (1998) pointed out that the metacognitive discourse has an effect on the development of scientific reasoning. As stated above, it is clear that social interaction at reasoning tasks influences reasoning strategy performance. Pearsall's study (1999) also demonstrated that socially scaffolded metacognitive exercise to some extent exerted effects on the development of scientific reasoning strategies. At her study, however, it is difficult to determine whether metacognitive exercise is effective in the absence of peer interaction.

Second, it is needed to examine if metacognitive exercise on scientific reasoning strategies has effects on transfer within physical science domains. One major purpose for metacognition research stems from the desire to develop instructional techniques to aid the utilization and transfer of learning strategies, and one of the important objectives of education is transfer (Osborne, 1998; Sigler, 1997). There are some evidences that metacognitive training has the potential to improve transfer. A set of studies by Berardi-Coletta *et al.* (1995) showed that near-transfer (transfer to a very similar, yet more difficult, task) was improved for students who were encouraged to become more metacognitive (via prompts designed to facilitate self-monitoring). Franks *et al.* (1982) also showed spontaneous transfer to new passages that were similar in nature to the ones trained on.

Pearsall's samples, however, did not show the transfer of training to other similar task. The lack of transfer at her work raises the possibility of effects of affective investment within social science domain. Kuhn *et al.* (1995) found that children applied the domain-general science reasoning skills differently when they explored tasks with physical science content as opposed to when the same subjects worked on isomorphic tasks with social science content. One of explanations for such a difference in application is that individuals may place more affective investment in their social science beliefs than their physical science beliefs, thus having stronger theory-driven biases in reasoning in the social over physical (Kunda, 1990). Therefore, the lack of transfer at Pearsall's work may possibly be resulted from children's much more prior knowledge or more affective investment in social content. Thus, it is needed to examine if metacognitive exercise has the effects of transfer within physical science domains placed less affective investment.

Third, it is needed to investigate whether there are no other developmental patterns of scientific reasoning strategies except Kuhn's model. Kuhn and her colleagues discovered that students used multiple strategies over time and even during single session

(Kuhn, 1997; Kuhn *et al.*, 1992, 1995). Kuhn also has developed a model that captures the process of change from initial to a more advanced level of strategy usage. During the beginning state, the weaker strategies are more heavily employed and the stronger strategies only occasionally used. By the final state, strategy usage has inverted so that the most efficient strategies are the most frequently used. Thus, according to Kuhn's model, the development of scientific reasoning strategies is a process of gradual change rather than a process of fundamental change. Just as they suggested, do children go through the developmental process of reasoning strategies over time? Could there be other developmental phases of reasoning strategies like different positions on the process of conceptual change? If several developmental phases exist, how does metastrategic exercise affect on the pattern of change in strategy usage? These issues also need to be examined.

To do those, this study is intended to examine the effects of metastrategic exercise to monitor, evaluate, and control fictional children's strategies of variable control within physical science domains. The exercise is designed for children to work alone the metastrategic intervention task. In addition, the study is microgenetically conducted in order to investigate the developmental patterns in children's strategy usage.

Thus, this study focuses on the following research questions: (1) Does metastrategic exercise on variable control strategy take effect on the development of the strategy performance?; and (2) How does each child's strategy to control variables change over a given period? and Does the metastrategic exercise influence the developmental patterns?

METHODOLOGY

Participants

Participants were 90 fifth graders in two classrooms of an elementary school located in Incheon metropolitan area. Of the 90 participants, 47 were girls and 43 were boys. Five children were dropped from the analyses due to irregular attendance or normal learning disability. Therefore, final sample consisted of 44 girls and 41 boys, respectively. Two classrooms were divided into an experimental group and a comparison group. Children in the experimental group were 21 girls and 21 boys. For the comparison group, 20 boys and 23 girls participated. The socioeconomic status of most children's families is lower-middle class. The mean age of the children was 11.6 years at the beginning of this study. The reasons why the classrooms were chosen as sample were as follows. First, there was no difference in academic achievement level on the Korean language, mathematics, social studies, and science between the classrooms. Second, the children in these classes have been taught in similar classroom settings; the teachers had similar career and same gender.

Tasks

Tasks in this study consisted of three tasks: main task, transfer task, and intervention task. The main task and the transfer task were activities to require multivariable causal reasoning. The intervention task consisted of a range of questions which encourage children in experimental group to reflect on other fictional children's strategies to control variables. The following details these tasks.

Main Task. The goal of main task was to examine which features affect the speed of boats towed in a linear canal. The task consisted of a computerized simulation and a copy of paper-and-pencil material. The task was adapted from Schauble, Klopfer, & Raghavan (1991), with major difference that the task was presented on a PC, had 4 variables, and used a copy of paper-and-pencil material. The simulation was a web-based scientific reasoning program created by using JAVA (Fig. 1).

The model boat was towed in a miniature canal over a seven second period. The model boat ran on a linear canal with four numbered zones marked by flags. There were four flags along the boat's course that corresponded to the four different speeds the boat could reach in seven seconds. The boat's features could

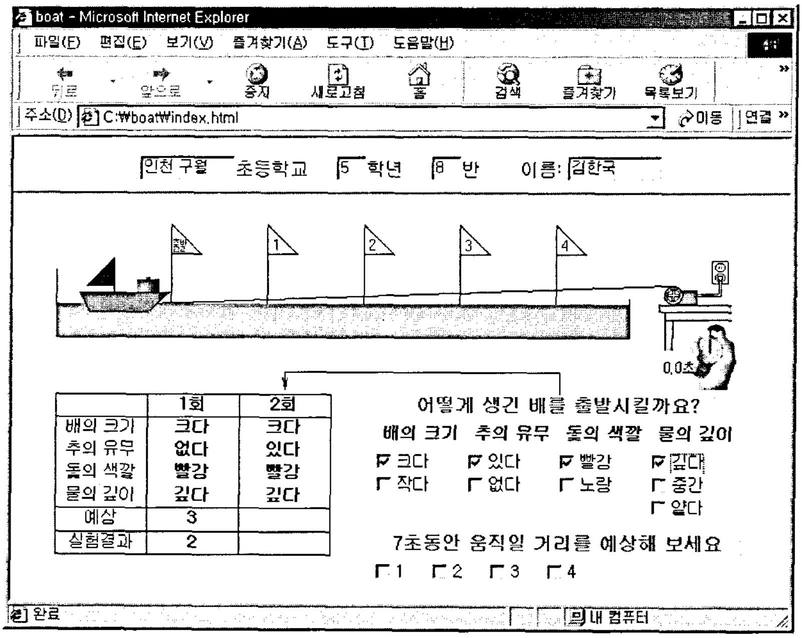


Fig. 1. A sample of computerized reasoning task (main task).

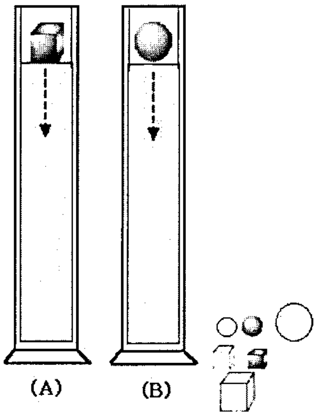
1. What feature(s) do you want to examine at two given trials? Choose the feature(s) to investigate at the given trials.
   ▷ Boat size (   ) ▷ Weight (   )
   ▷ Sail color (   ) ▷ Water depth (   )
2. By clicking on the image, select an instance of the first trial to examine according to your plan.
3. Predict the outcome on your selection and run the model boat.
4. Try again 2.~3. for the second trial.
5. Now, write results of your two given trials at the next table.

	The 1st trial	The 2nd trial
Boat size		
Weight		
Sail color		
Water depth		
Predicting		
Outcomes		

Fig. 2. A paper-and-pencil material of main task.

be changed by clicking on the image. Each record contained descriptions of four features which were selected by each child: boat size (large/small), weight (presence/no), sail color (red/yellow), and water depth (deep/medium-deep/shallow). Children were free to choose instances, predict the outcomes, and run the simulation. And then the predictions and actual outcomes were provided. There were 24 possible unique combinations of features. Sail color had no effect on outcome. Boat size had a simple causal effect, weight had a causal effect in interaction with boat size (it has an influence only with small boats), and water depth was a three level feature having a partial and curvilinear effect (the deep and medium-deep levels did not differ from one another but yielded a faster outcome than the shallow level).

The paper-and-pencil material consisted of a series of questions on children's investigation only at initial



A Boy called Cheol-Su intends to investigate which features make a difference in how fast objects sink in water · · · The object's size is either large or small. The object's color is either black or white. The shape is sphere or cube · · · If the object color makes a difference then black objects will sink faster than white objects, or white objects will sink faster than black objects. If the color makes no difference, then black objects or white objects will sink the same speed. Your job is to do your best with Cheol-Su to find out which features make a difference and which features make no difference in how fast the objects sink.

To begin with, you should choose for what you would like to find out about at the first trial and should select features according to your intent. After selecting experimental conditions, you should fill up the outcomes with reference to the given result table.

1. What feature(s) do you want to examine at a given trial? Choose the feature(s) to investigate at the given trial.
   ▷ Object's shape ▷ Object's size ( ) ▷ Object's color ( )
2. Select instances of the first trial to examine according to your plan.
3. Now, write your selection at the next table.

	Cylinder A	Cylinder B
Object's shape		
size		
color		

Fig. 3. A paper-and-pencil material of transfer task.

two trials in each session (Fig. 2). Researcher read each question aloud to insure that all children were able to understand the questions. Data of each child's strategy performance on main task were acquired from the his/her literal responses on these questions. After completing the initial two given trials, children in the two groups freely ran the computerized scientific reasoning task during the rest of each session.

The main task lasted 30 minutes at the each session. Children worked independently, unobserved by the investigator, thus reducing the risk of demand characteristics affecting performance.

Transfer Task: This task goal was to determine which features influence the rate of objects' sinking into water (Fig. 3). This task was adapted from Penner & Klahr (1996), with major differences that the task was presented as a copy of paper-and-pencil version, and had three features; shape (sphere/cube), size (large/small), and color (black/white). In addition, unlike original dimensions, it included a noncausal feature (object's color) and excluded a causal feature (object's material). There were eight possible unique combinations of features. This task was almost isomorphic causal reasoning task as compared with main task.

Each child was asked to choose which feature (s) they intended to investigate at a given trial. Then (s) he was prompted to select two instances according to his/her intent. The task lasted 20 minutes. Like at the main task, researcher read the questions of the transfer task aloud to insure that all children were able to understand them.

Intervention Task: In this task, children in experimental condition were asked to reflect on 'fictional' children's strategies to control variables on the main task through intervening problems (Fig. 4). These problems consisted of metastrategic activity such as monitoring, evaluating, and controlling of the fictional

Thinking about | Young-Jun's and Sung-Hee's work | No ( ) Name ( )

※ This is Young-Jun's and Sung-Hee's work to examine if the existence of weight makes a difference or not.

Young-Jun	1st	2nd
Boat size	small	large
Weight	yes	no
Sail color	yellow	red
Water depth	deep	deep
Predicting	2	3
Outcomes	3	2

Sung-Hee	1st	2nd
Boat size	large	large
Weight	yes	no
Sail color	red	red
Water depth	medium	medium
Predicting	3	2
Outcomes	2	2

[1] How are each feature selected by Young-Jun and Sung-Hee? (Mark 'V' on each feature)

Young-Jun
- ▷ Boat size [same ( ) / different ( )]
- ▷ Weight [same ( ) / different ( )]
- ▷ Sail color [same ( ) / different ( )]
- ▷ Water depth [same ( ) / different ( )]

Sung-Hee
- ▷ Boat size [same ( ) / different ( )]
- ▷ Weight [same ( ) / different ( )]
- ▷ Sail color [same ( ) / different ( )]
- ▷ Water depth [same ( ) / different ( )]

[2] What grade would you give Young-Jun and Sung-Hee on their selections about boat features, respectively? Why do they deserve these grades? (Write down your answer)

Young-Jun [ ] ----------

Sung-Hee [ ] ----------

[3] Suppose that Young-Jun attempted to as follows in order to investigate if the existence of weight makes a difference or not. If you are Young-Jun, how do you select each feature at the second experiment to do that? (Write down your choices)

	1st	2nd	→ 2nd
Boat size	small	large	
Weight	yes	no	
Sail color	yelbw	red	
Water depth	deep	deep	
Predicting	2	3	
Outcomes	3	2	

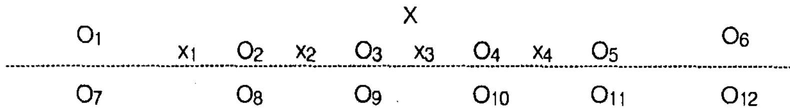
▷ Put down the reason of your choices

Fig. 4. An example of intervention task.

children's strategy usage. Children in the experimental group looked at a total of four examples of fictional children's strategy performance on control of variable before they began the 2nd~5th main sessions. This activity was conducted without providing feedback regarding their responses. The task lasted 15 minutes at each intervention session.

Procedure

A nonequivalent control group and microgenetic research design was used in this study (Fig. 5). The two groups participated in repeated engagement with main task over a period of six sessions. Before the experimental group began the 2nd~5th main sessions, the group took part in four intervention sessions in which the group reflected on how fictional children had performed the strategy of variable control at the main task. During the same period, the comparison group participated in four sessions in which they read unrelated scientific texts and answered questions at



X : Metastrategic exercise
x_1 ~ x_4 : the 1st ~ 4th intervention sessions
O_1 , O_7 : the **1st test** on main task (performance at the first session) and **pretest** on transfer task
O_2~O_5 / O_8~O_{11} : the **2nd, 3rd, 4th,** and **5th tests** on main task (performance at the 2nd~5th sessions, respectively).
O_6 , O_{12} : the **6th test** on main task (performance at the sixth session) and **posttest** on transfer task

Fig. 5. Research design.

the texts. At the first session and the last session, the two group participated in transfer task. At one-month delayed posttest, the two groups again took part in the main task.

Data analysis

There were two sources for data analysis: (1) for the main task, two groups' performance of variable control strategy at each session and one-month delayed posttest; and (2) for the transfer task, two groups' performance on the strategy at the pretest and the posttest. Data on children's strategy performance at main task and transfer task were acquired from children's literal responses the paper-and-pencil materials.

To examine research question 1, quantitative data analysis was used. Data on the main task and on the transfer task were subjected to one-way ANOVA statistics, because tests of homogeneity were not violated. Next, microgenetic data analysis was used in order to determine research question 2. Each child's performance on main task over a period of six sessions was examined in order to identify his/her developmental patterns in strategy usage. And then the patterns were compared across the two classrooms to determine whether there was significant differences between the two groups.

RESULTS AND DISCUSSION

Research question (1): Does metastrategic exercise on variable control strategy take effect on the development of the strategy performance?

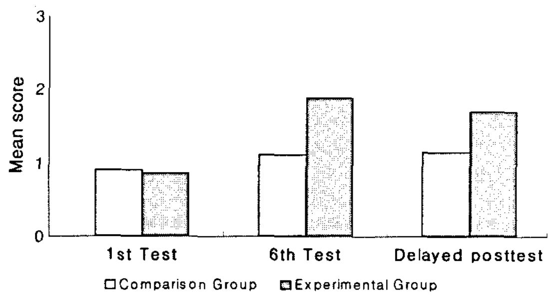


Fig. 6. Mean on control of non-target variables at the 1st test, 6th test and one-month delayed posttest.

Control of variables refers to the ability that a child can control non-target variables not being examined and manipulate a target variable being examined. Children's scores were obtained from their responses to the paper-and-pencil material of the main task. Children's responses were assigned a score of 0 to 3 depending on the number of controlled non-target variables. Children with higher level reasoning would control three features to test rather than none, one, or two features at the main task. Thus, higher scores indicate better reasoning ability.

As shown in Fig. 6, children in experimental group improved markedly in the strategy usage over children in comparison group. For the experimental group, the mean score on control of variables improved from .85 (SD = 1.09) at the 1st test to 1.88 (SD = 1.15) at the 6th test (Table 1). Although the comparison group's mean score also ascended from

Table 1. Mean score and standard deviation on control of non-target variables at the 1st and the 6th session, and one-month delayed posttest

	n	1st Test	6th Test	Delayed posttest
Total				
M	85	.88	1.49	1.41
(SD)		(1.02)	(1.23)	(1.26)
Condition				
Experimental	42			
M		.85	1.88	1.69
(SD)		(1.09)	(1.15)	(1.27)
Comparison	43			
M		.90	1.11	1.13
(SD)		(.97)	(1.19)	(1.20)

Table 2. One-way ANOVA results on control of non-target variables at main task

		SS	df	MS	F
1st Test	Between Groups	.05	1	.05	
	Within Groups	88.77	83	1.07	.04
	Total	88.82	84		
6th Test	Between Groups	12.42		12.42	
	Within Groups	114.82	1 83 84	1.38	8.98**
	Total	127.24			
Delayed posttest	Between Groups	6.44	1	6.44	
	Within Groups	128.13	83	1.54	4.17*
	Total	134.58	84		

*p<.05, **p<.01.

.90 (SD = .97) to 1.11 (SD = 1.19), an ANOVA found a significant difference between two conditions, F = 8.98, p<.01 (Table 2). At the first test, 18, 15, 6, and 4 children in the comparison group controlled none, one, two, and three features, respectively. At the sixth test, 19, 9, 6, and 9 children in the group controlled from none to three features. For the experimental group, at the first test, 22, 10, 4, and 6 children controlled none to three features, respectively. At the final test, 8, 6, 11, and 17 children in the group controlled none to three features.

To examine that there was the effects of retention, data for control of variables were subjected to one-way ANOVA statistics. The result also yielded significant differences between two groups F (1, 83) = 4.17, p<.05 (Table 2). While comparison group almost remained constant, experimental group somewhat regressed at the delayed posttest in contrast with at the 6th test.

The performance on transfer task indicates the extent to which improvements on main task generalize to an entirely new context. Children's scores on variable control strategy were obtained from their responses to the paper-and-pencil material of transfer task. Like at the main task, children's responses on transfer task were assigned a score of 0 to 2 depending on the number of controlled variables. The two groups were nearly identical at the pretest. The mean score for the experimental condition was .21 (SD = .41) and .23 (SD = .61) for the comparison condition. At the posttest, however, children in the experimental condition had more controlled non-target features (M = .78, SD = .89) than did children in the comparison condition (M = .41, SD = .69). One-way ANOVA found a significant difference between conditions, F (1, 83) = 4.43, p<.05.

In sum, the results indicated that the metastrategic activity in a single condition was effective on the development of the scientific reasoning strategy at the main task and that the effects of intervention was to some extent stable. Although the transfer task was almost isomorphic multivariable causal structure as compared with the main task, the results also indicated that a learned strategy could be utilized in another contexts. In connection with results of Pearsall's study (1999), this result suggested the possibility that the lack of transfer shown in her study resulted from children's more affective investment in social science reasoning tasks as Kuhn *et al.* (1995) and Kunda (1990) argued.

Research question (2): How does each child's strategy to control variables change over a given period? and does the metastrategic exercise influence the developmental pattern?

To examine these questions, this study was micro-genetically conducted over a period of six days with a same reasoning task. Data on each child's strategy performance by sessions were obtained from his/her literal responses to the paper-and-pencil materials of the main task, and then his/her strategy performance was charted as shown in Fig. 7.

Results in the study showed four typical patterns: Type A, Type B, Type C, and Type D. Type A was

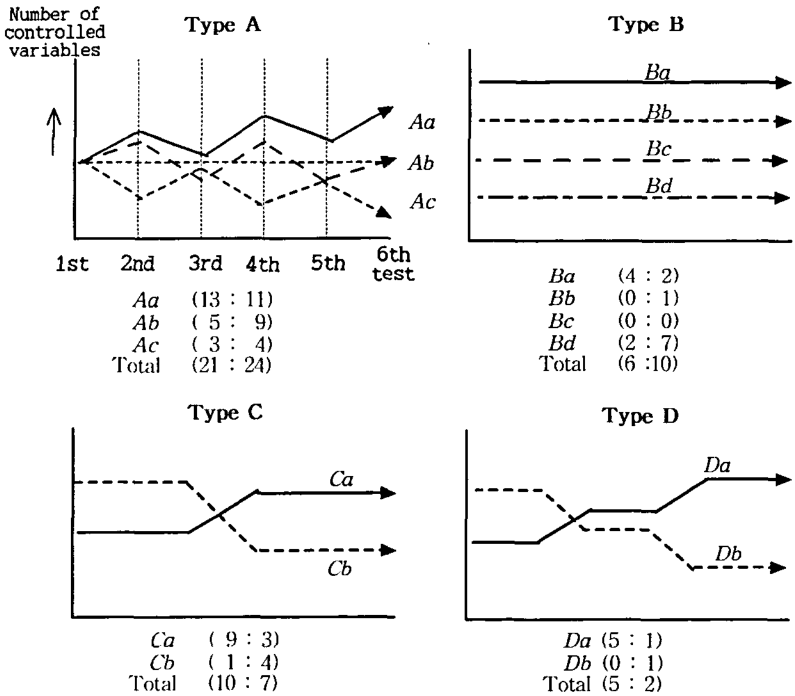


Fig. 7. Developmental patterns in the strategy usage on control of non-target variables over six sessions.

a developmental pattern which was consistent with models suggested by Kuhn *et al.* (1995) and Siegler (1995) who identified variability in a strategy usage. Type B was a pattern which remained unchanged and consistent over time. Type C was a pattern that showed a fundamental change between the weaker strategy and the stronger strategy. Finally, Type D was a pattern that showed a stage-like fundamental change.

Forty five children (52.9%) in two groups made Type A: 50.0% in the experimental group and 55.8% in comparison group. This type could be divided into three subtypes: Aa, Ab and Ac. The subtype Aa was an improving pattern, Ab was a pattern returning to initial state, and Ac was a retrogressive pattern. Aa was made by 30.9% and 25.5% in experimental group and comparison group, respectively. Ac was shown by 7.1% and 9.3% in experimental condition and comparison condition, respectively.

Type B was made by 18.8% of children in two groups: 14.2% in the experimental group and 23.2% in comparison group. Type B could be divided into four subtypes: Ba, Bb, Bc, and Bd. While Ba was a case constantly shown the most efficient strategy usage of all others, Bd was a diametrical pattern against Ba. 4.7% in experimental group and 16.2% in comparison group showed the subtype Bd. 9.5% in experimental condition and 4.6% in comparison condition made Ba. Only one child in comparison group showed Bb and none in two groups made Type Bc.

Seventeen children (20.0%) in two groups showed Type C:23.8% in experimental group and 16.2% in comparison group. This pattern could be divided into two subtypes: Ca and Cb. While Ca was a pattern to move from the weaker strategy to the stronger strategy, Cb was a pattern to move conversely as compared with Ca. The subtype Ca was made by 21.4% in experimental group and 6.9% in comparison group. Cb was shown by 2.3% and 9.3% children in experimental group and comparison group, respectively.

Seven (8.2%) in two groups showed Type D. While Da was a progressive pattern, Db was a retrogressive pattern. Da was made by 11.9% and

Table 3. Performance on control of non-target variables at one-month delayed posttest among children who made subtype Ca or Da

Condition	Name	1st test	2nd test	3rd test	4th test	5th test	6th test	Delayed posttest
Comparison Group	PYH	1	1	1	2	2	3	2
	JHJ	0	0	0	0	1	1	0
	CDS	0	1	1	1	1	1	1
	LSJ	1	3	3	3	3	3	3
Experimental Group	KD	1	1	1	1	1	2	0
	PKY	0	1	1	3	3	3	3
	LJR	0	0	0	0	3	3	1
	YHS	1	3	3	3	3	3	3
	KJS	2	2	3	3	3	3	3
	BTH	0	3	3	3	3	3	3
	SJW	0	1	3	3	3	3	3
	LSH	0	0	0	3	3	3	3
	JSK	0	0	3	3	3	3	3
	KJR	0	0	3	3	3	3	2
	KMA	0	2	2	2	2	2	2
	PSH	1	3	3	3	3	3	3
	KEY	0	0	0	1	2	2	2
	PMK	1	2	2	2	3	3	2

*The Arabic numerals mean the number of controlled non-target variables.

2.3% in the experimental and the comparison condition, respectively. Only one child in comparison group showed Db.

At one-month delayed posttest, 66.7% out of 18 children made subtype Ca or Da maintained the patterns without any variation in the strategy usage (Table 3). While 50.0% in the comparison group persisted the developmental patterns, 71.4% in the experimental group maintained the patterns at the delayed posttest.

Result in this study suggests a possibility that each child undergoes different developmental processes in his/her strategy usage on a reasoning task. That is, some children went through the process of gradual changes (Type A) and others went through the process of fundamental changes (Type C and D). For the percentage of children who made fundamental changes, the experimental group showed higher rate than did the comparison group. Thus, the results to some extent demonstrated metastrategic exercise about variable control strategy affected on the developmental patterns in strategy usage. The findings also indicated likelihood that the metastrategic exercise gave opportunities of effective 'Ahas' experience, defined as metacognitive experience by Garner (1994). Garner suggested that this experience would be most likely to do with progress toward the goal of completing a study activity successfully. It might be the same as at the development of scientific reasoning strategies.

CONCLUSIONS

The results of this study reveals three findings as follows. First, the metastrategic exercise on the strategy of variable control has positive and long-standing effects on the strategy performance at a reasoning task. The exercise also takes effect of near-transfer. Taking into consideration only about sixty minutes of metastrategic practice, the results provides the effectiveness of metastrategic exercise on scientific reasoning strategies.

Second, in a scientific reasoning task, each child seems to go through one out of two developmental patterns in his/her usage of reasoning strategies: gradual change or fundamental change. Considering the ratio of fundamental change pattern between the two groups, it is clear that metastrategic exercise upon a reasoning strategy influences on the developmental pattern.

This study leaves several avenues open for future research as follows. First, results in this study must be replicated within different cohorts or by using different research methods because of several caveats such as sample size or children's handicap of literal response.

Second, it is needed to refine the types of metastrategic exercise. For example, children in this study were not given a feedback on their metastrategic activities. Thus, future research is needed to consider various feedback methods, such as group or class discussion.

Third, the effect of transfer in this study was investigated through the other reasoning task with very similar structure in comparison with one reasoning task. Thus, it is also needed to examine if there is 'far' transfer to dissimilar reasoning tasks or not.

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