A Study of Logical Operations in Programming Education Based on Elementary Students' Scratch Programming Tasks

IlKyu Yoon† JongHye Kim†† WonGyu Lee†††

論理的思考と問題解決能力に関連したプログラミング教育が数多く研究されている．しかし，ほとんどのプログラミング教育と論理的思考の相関を探る研究は GALT（論理的思考のグループ評価）のような一般的な論理的思考力テストを使用している．本稿では，小学生対象の創意的情報科学教室で実施された，「スクラッチ」による子どもたちのプログラミング活動を分析する．GALT による論理的思考の予備実験により，教室に参加したすべての子どもが具体的操作期であると判明した．ピアジェの理論によると，具体的操作期のほとんどの子どもは比例論理を備えている．しかし，テストを受けた子どもは、比例論理や変数を扱う問題を解いている．子どもたちのテスト結果に基づき，我々はスクラッチのプログラミングタイルを分析する．本研究は、子どもはスクラッチプログラミング学習の初期では比較的低い論理的思考プログラミングタイルを用い，授業が進むにつれ自然により高い論理的思考プログラミングタイルを用いていることを示す。

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There are researches on programming education which are related to proportional reasoning and controlling variables. However, a majority of such researches uses general logical thinking test, such as GALT(Group Assessment of Logical Thinking) for evaluation. In this paper, we have analyzed students' Scratch programming tasks after programming education, which have joined our Creative-Informatics camp classes. As a result of analysis, a use of blocks related to proportional reasoning and controlling variables increased step by step that programming education were progressed. Also, We found that students used more proportional reasoning related blocks than controlling variables related blocks in animation tasks and more controlling variables related blocks than proportional reasoning related blocks in game tasks. In this research, we suggested that animation task be prior to game task when designing programming education to enhance logical thinking ability of students in concrete operation period.

1. Introduction

There have been many studies that the programming learning could improve the problem-solving ability and logical-thinking ability[1],[2],[3]. In particular, there have been many studies that many students in a concrete operational period were apt to improve the logical thinking ability[4][5]. Kang(2004) suggested that there be meaningful relationship between fundamental programming education for elementary school students and logical thinking[4]. Kim(2007) suggested that programming education be effective to understand abstract and logical concepts for student in a concrete operation period[5].

. In 2005, the 'Guideline for ICT(Information and Communications Technology) Training' revised the programming learning from Grade 3 in concrete operational period in Korea[6]. However, using general programming languages in classes and educating students to become experts on that language require too much time and it is unaffordable for them. To decrease the burden, educational programming languages which adapt to K-12 cognitive level and learning ability have been proven to be useful. Representatives of such languages include 'Dolittle[7]', 'Scratch[8]' and 'Squeak[9]'.

There are many researches on programming education which is related to logical thinking. Although there were studies that programming learning was associated with the logical thinking ability, only few of them approach the relationship between programming learning and logical thinking ability in detail. Unfortunately there are researches on programming education which is related to some of subordinate concepts of logical thinking[10][11]. Choi(1994) has examined effect of programming education and experiential education over logical thinking ability. He performed pre-test and post-test to investigate the effect using TOLT(Test of Logical Thinking) A, B. His conclusion was that the programming education is more effective to

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increase logical thinking and that have a influence on controlling variables and proportional reasoning[10]. Yoo(2007) has examined effect of 'Dolittle' programming tasks over logical thinking ability. He used GALT as pre-test and post-test to investigate the effect. His conclusion was that the subordinate concepts most influenced by the programming education was controlling variables and the second was proportional reasoning[11].

Likewise according to these researches, we may conclude that proportion reasoning and controlling variables, the subordinate concepts of logical thinking, can be improved through programming education. Most of those studies have used a GALT(Group Assessment of Logical Thinking)[12] test or a general logical thinking test to measure logical thinking ability[1],[4],[11] However, whether these standard logical thinking tests such as GALT can measure logical thinking ability used in programming or not might be questionable. Although correlation between GALT score and logical thinking ability in general seems to be reliable, there might be cognitive interference from prior knowledge (due to the fact that problem materials are based on science and mathematics), which can make the test unsuitable to measure logical thinking ability required in programming tasks.

Therefore, this study examined whether students in concrete operational period could develop their proportional reasoning and controlling variables in step by step during programming learning with Scratch.

2. A Subordinate Concept of Logical Thinking Ability Related to Programming Education

According to the Piagetian theory, elementary school students(year 8~13) belong to post-concrete operation period and to pre-formal operation period. Also, children from year 7 to 12 belong to concrete operation period and they are in the 1st to the 5th grade in Korea. Raven(1973) suggested that the logical operation growths in this concrete operation period be conservation, classification and seriation[14].

① Conservation : reasoning based on that volumes (ex. of liquid) do not change even if their shapes (ex. beakers) change.

② Classification : reasoning that can classify of something based on character.

③ Seriation : reasoning that can analyze the fundamental relationship of particular series and guess what comes next.

According to the Piagetian theory, children over 12 belong to formal operation period and they are in the 5th grade in elementary school in Korea. Moreover, children that belong to formal operation are capable of whole kind of logical operation[14].

① Proportional reasoning : reasoning based on that something (ex. weight of liquid) is proportional to other thing (ex. volume of liquid).

② Controlling variables : reasoning based on that some specific variables (controlling variables) determine the outcome

3. Operational definition and analysis criteria of operation blocks in scratch

3.1 Operational definition of utilizing blocks related to proportional reasoning

Students operate the blocks that specify the amount of sprite movement by a number and the movement is proportional to the specified number. Therefore, when students are comfortable with these kinds of blocks, they are supposed to acquire proportional reasoning. In this study, we classify the block categories containing logical operation concept related to proportional reasoning into motion, looks, and sound category. Also, the operational definition and criteria of student's task analysis are as following.

Table 1 The operational definition and criteria of student's task analysis

Scratch block categories	Operational definition of utilizing blocks containing logical operation concepts	Criteria for analysis of student's task
Motion	Operation blocks containing number value to move the sprite or to specify position.	• Using motion blocks containing number value input by student to move the sprite or to specify position?
Looks	Operation blocks containing number value to change the sprite looks or color.	• Using looks blocks containing number value input by student to change the sprite looks or color?
Sound	Operation blocks containing number value to change the music or sound.	• Using looks blocks containing number value input by student to change the music or specific sound?

3.2 Operational definition of utilizing blocks related to controlling variables

In scratch programming, controlling variables can change the outcome overall and it is the essential concept in the analysis of mutual relationship between students' own program and execution. In this study, we classified the block categories containing logical operation concepts related to controlling variables into control, sensing, and variables. Also, the operational definition and criteria of student's task analysis are as following.

Table 2 The operational definition and criteria of student's task analysis

Scratch block categories	Operational definition of utilizing blocks containing logical operation concepts	Criteria for analysis of students' task
Control	Operation blocks containing condition, repetition, broadcast to control and execute the program.	• Using control blocks to control the outcome?
Sensing	Operation blocks used as variables of control blocks to control and execute the program.	• Using sensing blocks as a variable in control block to control the outcome?
Variables	Operation blocks that can change the outcome according to factors which set variables and affect them.	• Setting and using variables blocks to change the outcome?

4. Methodology

We count all of the Scratch blocks of the tasks that students submit after their class.

4.1 Participants

The number of participants of Creative-Informatics camp held in 2008 was 8. Here are the true number : one 2nd grade student(year 9), five 3rd grade students(year 10), two 4th grade students(year 11). The result of preliminary test was that all of students belong to the concrete operation period.

4.2 Procedure

Creative-Informatics camp was conducted for 4 hours a day covering 5-day period. Programming education courses are comprised of producing animation and producing game.

Logical thinking ability test with GALT was executed before the programming education, the students took logical thinking ability test with GALT for 30 minutes. The GALT, a logical thinking test that measure general logical thinking ability consists of six subordinate concepts : conservation, proportion reasoning, controlling variables, probabilistic reasoning, correlational reasoning and combinatorial logic.

As shown in Table 3, we explained the fundamental function of 8 categories of Scratch blocks to the students and make an animation program, 'Funny Conversation'. In the second class, the students made another animation, 'Happen in the School'. They made a game program, 'Popping Ball' in the third class and another game program, 'Hunting Fish' in the fourth class. Lastly, they made game program, 'Mario'.

Table 3 Curriculum of Scratch class

	Educational Contents
Preliminary test	Logical thinking test(GALT)
1(3hour)	Introduce operation blocks, Producing animation (Funny Conversation)
2(4hour)	Producing animation (Happen in School)
3(4hour)	Producing games(Popping Ball)
4(4hour)	Producing games(Hunting Fish)
5(4hour)	Producing games(Mario)

5. Result

5.1 Changes in use of blocks related to proportion reasoning and controlling variables

As a result of study, a use of blocks related to proportional reasoning and controlling variables increased step by step in proportion as the programming education is in progress. The results of the analysis are as follows.

Firstly, among the 8 categories above, motion, looks, and sound blocks include proportional reasoning concept. As a result of analysis of Scratch task, the numbers of motion, looks, and sound blocks used in every class were as follows.

Table 4 Changes in using blocks related to proportional reasoning

Class	1	2	3	4	5	Total
Motion	24	121	97	96	225	563
Look	165	248	40	125	176	754
Sound	11	186	15	2	9	223
Proportional reasoning related blocks	200	555	152	223	410	

As shown in Table 4, among the operation block categories related to proportional reasoning, the 'looks' was used more frequently than any others in the whole classes. Also, proportional reasoning related blocks were used the most in the animation task, 'Funny Conversation'. The analysis of the frequency of each block is as follows. Firstly, the category 'motion' was most frequently used in the game task, 'Hunting Fish'. Secondly, the category 'looks' was most frequently used in the animation task, 'Funny Conversation'. Thirdly, the category 'sound' was most frequently used in the animation task, 'Funny Conversation'.

Fig. 1 shows the change of percentage of use of blocks related to proportional reasoning according to the analysis criteria.

We exclude the category 'sound' from Fig. 1 because the use of it is so biased according to the characteristics of tasks. As shown in Fig. 1, the percentage of use of proportion reasoning related blocks increased over all. In particular, the percentage of it was raised during the animation producing classes between 1 and 2, and percentage was raised during the game producing classes between 3 and 5.

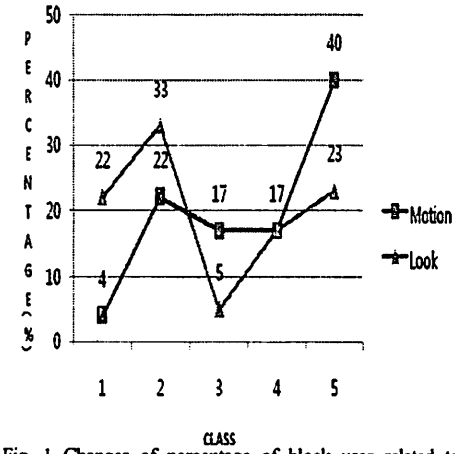

Fig. 1 Changes of percentage of block uses related to proportional reasoning

Secondly, among the 8 categories above, control, sensing, and variables blocks include controlling variables concept. As a result of analysis of Scratch task, the numbers of control, sensing, and variables blocks used in every class were as follows.

Table 5 Change of using blocks related to controlling variables

Class	1	2	3	4	5	Total
Control	151	260	209	393	349	1,362
Sensing	-	-	57	71	73	201
Variables	-	-	31	-	35	66
Controlling variables related blocks	151	260	297	464	457	

As shown in Table 5, the category 'control' of operation blocks was used more frequently than any other controlling variables related blocks in the whole classes. Also, it was the game task, 'Mario' that controlling variables related blocks were used the most. The analysis of the frequency of each block related to controlling variables is as follows. Firstly, the category 'control' block was used most frequently in the game task, 'Mario'. Secondly, the 'sensing' and the 'variables' block categories were used most frequently in game task, 'Hunting Fish'.

Fig. 2 shows the change of percentage of block uses according to analysis criteria related to controlling variables.

We exclude the category 'variables' block from Fig. 2 because the use of category 'variables' block is so biased according to the characteristics of tasks. As shown in Fig. 2, the percentage of use of controlling variables related block was increased over all. In particular, the percentage of it was raised during the producing classes between 1 and 2, and the percentage of it was raised rapidly during the game producing classes between 3 and 5.

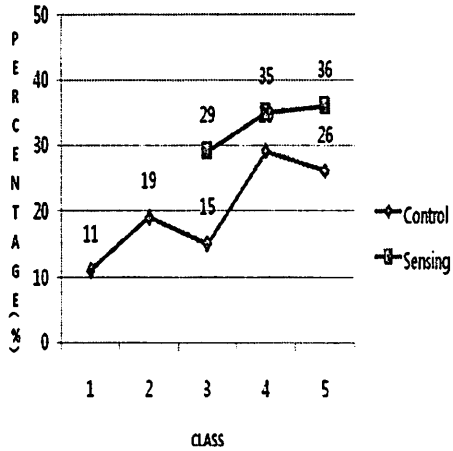

Fig. 2 Changes of percentage of block uses related to controlling variables

5.2 Changes of operation blocks in subject

We analyze programming education separating into two subjects, a producing animation task and a game task. As a result of our analysis, there were differences in uses between proportional reasoning related blocks and controlling variables blocks along with their subject characteristics and the results were as follows.

Firstly, the animation task was done in the classes 1 to 2. Also the analysis of operation blocks according to the animation task was as follows.

Table 6 Analysis results of operation blocks in the animation task

		Class 1	Class 2	Total
Proportional reasoning	Motion	24	121	355
	Look	165	248	
	Sound	11	186	
Controlling variables	Control	151	260	109
	Sensing	0	0	
	Variables	0	0	

As animation tasks proceeded, the percentage of use of operation blocks was raised over all except sensing and variables blocks categories. Students were educated in the first class about the whole categories of blocks including sensing and variables categories but they did not use those blocks. They felt difficulty to use sensing and variables block categories in the animation task classes. Also, students' use of control block categories leaned to the broadcast operation blocks. As a result, we found that until the second class, students could not understand clearly how to control a program using the blocks related to controlling variables.

Secondly, the game task was done in the classes 3 to 5. Also the analysis of operation blocks according to the game task was as follows

Table7 Analysis results of operation blocks in the game task

		Class 3	Class 4	Class 5	Total
Proportional reasoning	Motion	97	96	225	410
	Look	40	125	176	
	Sound	15	2	9	
Controlling variables	Control	209	393	349	457
	Sensing	57	71	73	
	Variables	31	0	35	

As an animation task proceeded, the percentage of use of operation blocks was raised over all except the sound block category. In particular, students were using controlling variables related blocks more than proportional reasoning related blocks in the game task. Also, students used the sensing and the variables block categories more easily which were never used in the classes 1 to 2. Moreover, the results of Scratch task analysis say that students used control category blocks in free and various ways. We found that students' controlling variables abilities were developed after their proportional reasoning abilities were developed. This is strongly related to the theory that children in pre-formal operation period can perform proportional reasoning and children in post-formal operation period can perform controlling variables [14].

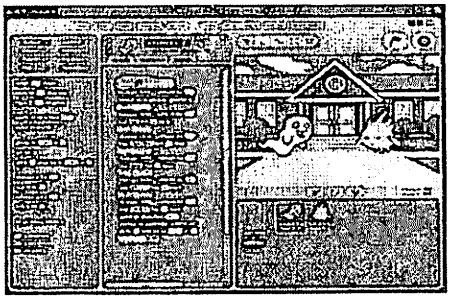

Fig. 3 Example of animation task

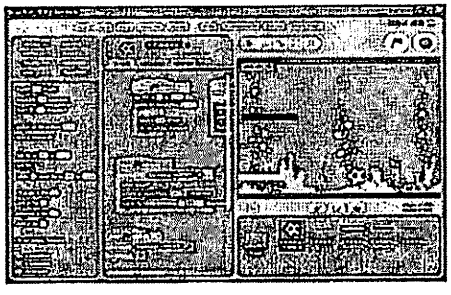

Fig. 4 Example of game task

6. Conclusion

In this research, we have examined how the children in the concrete operation period can be connected to the proportional reasoning and controlling variables which belong to the formal operation period using the programming education. In the process of this study, the following facts were found.

Firstly, the use of blocks related to proportional reasoning and controlling variables was raised over all as the programming education proceeded. According to the result of our analysis, we found that students in the concrete operation period could perform proportional reasoning and controlling variables which are of logical operations only possible in the formal operation period by the programming education. The looks category of operation blocks was used more frequently than any other proportional reasoning related blocks in the whole classes. Also, the control category of operation blocks was used more frequently than any other controlling variables related blocks in the whole classes.

Secondly, the programming education proceeded from the producing animation tasks to the producing game tasks. As a result of the task analysis, there were differences in uses between the proportional reasoning related blocks and the controlling variables blocks by subject characteristic. We found that students used more proportional reasoning related blocks than the controlling variables related blocks in the animation tasks. On the contrary, they used more controlling variables related blocks than proportional reasoning related blocks in the game tasks. This result is related to the theory that children in pre-formal operation period can perform proportional reasoning and children in post-formal operation period can perform controlling variables [14]. Therefore, we suggested that an animation task be more effective to develop the student's proportional reasoning by programming education. Also, a game task is more effective to develop the student's controlling variables by programming education.

According to this research, following statements should be considered. Proportional reasoning related education is prior to controlling variables related education in programming education for concrete operation period students. Also, proportional reasoning can be developed through animation tasks while controlling variables can be develop through game tasks. Therefore, animation tasks are prior to game tasks to design a programming education for the students in a concrete operation period.

It is difficult to say clearly that students can perform proportional reasoning and controlling variables related thinking because the number of participants of this research was too small. However, we could find clearly that students could use proportional reasoning related blocks naturally through the Scratch programming. We also found that the Scratch programming helped students to control a operation as they want by controlling variables related blocks.

Further direction of this research will be to analyze the understanding rate of logical operation concepts of students both with and without Scratch programming experiences. Moreover, not the simple block count, but the thorough analyses of students-developed programs are in order.

7. Reference

[1] YuSoon Lee.(1995), Computer Programming Education for the Extension of Logical Thinking and Solving Faculties

[2] MiYeoun Jeoung(2008), The Effects of Algorithm Learning with Squeak Etoys on Middle School Students' Problem Solving Ability.

[3] Alex Repenning(1994), Programming as Problem Solving: A Participatory Theater Approach, ACM.

[4] HyeJin kang(2004), Analysis of Children's Logical Thinking Improvement with Basic Programming Ability.

[5] JongHye Kim(2007), Comprehension of OOP Concepts using Dolittle in elementary school.

[6] Ministry of Education & Human Resources Development(2005), Guideline for ICT(Information and Communications Technology) in elementary and secondary school..

[7] S.Kanemune, et al.(2004), Dolittle-experiences in teaching programming at k12 schools

[8] MIT media LAB.(2007), http:// scratch.mit.edu

[9] Kay, A.(2007), Children Learning by Doing Squeak etoys on the OLPC XO.

[10] GuenSeob, Choi(1997), The Effect of LOGO Programming & Experiential Instruction on Student's Logical Thinking.

[11] SeungWook Yoo(2007). Improving K-12's Logical Thinking Abilities using Educational Programming Language 'Dolittle'.

[12] Yeany R.H., Padilla M. J., and Roadranka, V(1983), The construction and validation of group assessment of logical thinking.

[13] Piaget, J. & Inhelder, B(1958). The Growth of Logical Thinking from Childhood to Adolescence.

[14]Raven, R. J(1973). The Development of a Test of Piaget's Logical Operations.