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TRIAL OF PROGRAMMING EDUCATION FOR DEVELOPING ABILITIES OF SHIFTING VIEWPOINT IN ELEMENTARY SCHOOLS: THROUGH PROGRAMMING LEARNING ACTIVITIES USING ROBOTS

Hironori Sasaki
Chuugokugakuen University, Okayama, Japan
hironori_sasaki@sky.megaegg.ne.jp

Abstract

We organised learning activities for programming with a humanoid robot "Robohon" and conducted trial lessons with 73 third-grade elementary school students with the aim of cultivating their ability to shift their viewpoint at the physical level, the social level, and the third-person viewpoint. By shifting the viewpoint to Robohon the programming activities were adopted as those for cultivating each skill in the class. To measure the effectiveness of the learning activities, four tasks were used. The first was based on Piaget's "Three Mountains Problem", the second was a task to examine the developmental level of the role-taking ability, and the third task was a "Sally and Anne" test to measure the taking of a third-person viewpoint. Those were used in the pre- and *post- surveys. Also included in the evaluation was a task to create a flowchart that the children produced in class. As a result of the study, no significant effects on these three abilities were confirmed from the pre- and post-surveys using the three tasks, but the flowchart worksheets created in class indicated that the children were thinking from the viewpoint of others.*

Keywords

Programming Education, Shifting Viewpoint, Role-Taking Ability, Humanoid Robot, Robohon

1. Introduction

The author has positioned information morality (information ethics) as part of moral education and has developed various teaching methods and materials to support young children's moral development (Sasaki, 2016, 2019). However, when these lessons were trialed in elementary schools, it was observed that children found it challenging to reason about the emotions and thoughts of others. This difficulty was attributed to the underdevelopment of their role-taking abilities. According to Selman & Byrne (1974), the role-taking ability develops in five levels: Level 0: Self-centered role-taking (ages 3–5) ; Level 1: Subjective role-taking (ages 6–7); Level 2: Second-person commensurate role-taking (ages 8–11); Level 3: Third-person role-taking (ages 12–14); Level 4: Generalized other role-taking (ages 15–18).

With the introduction of programming education in Japanese elementary schools in April 2020, there has been increasing interest in its educational applications. As a result, the development of new teaching materials and instructional methods has been actively pursued. To this end, this study examines the potential of programming education in fostering role-taking abilities. Specifically, it is hypothesized that programming humanoid robots to shift perspectives and simulate interactions may enhance students' ability to adopt different viewpoints, thereby contributing to their role-taking abilities. Therefore, the purpose of this study is to develop the learning activities and assess whether these activities contributed to perspective shifts at the physical and social levels and role-taking abilities of elementary school students.

2. Prior Studies

Initially, the study planned learning activities in early childhood and elementary education consisted of three sequential steps:

1) Physical-Level Learning Activities: Developing the ability to shift perspectives at the physical level.

2) Social-Level Learning Activities: Acquiring the ability to reason about the emotions and thoughts of others.

3) Third-Person Perspective Learning Activities: Encouraging objective analysis of problem situations to further develop role-taking abilities.

However, previous trials of physical-level learning activities conducted with 5- to 6-year-old children suggested that young children struggle with changing perspectives at this level (Sasaki, 2020, 2022). Furthermore, a survey of young children indicated that the ability to shift perspectives at the physical level develops independently of social-level role-taking abilities (Sasaki, 2023a). Similarly, a survey of elementary school children also suggested that these two abilities develop independently (Sasaki, 2023b). Based on these findings, the study revised its framework, concluding that physical- and social-level learning activities can be organized simultaneously rather than sequentially.

3. Methods

3.1 Development of Learning Activities

Since the sequential progression from physical-level to social-level learning activities was reconsidered, these activities were conducted simultaneously. The activity to promote third-person role-taking was integrated into the social-level learning activities.

3.1.1 Goals of Learning Activities

The primary objective of the programming learning activity using Robohon is to foster perspective-shifting at both the physical and social levels while enhancing students' role-taking abilities. Additionally, students are expected to understand the fundamental programming concepts of sequential execution, iteration, and branching and apply these principles in the activities while developing flowcharts.

3.1.1 Lesson Plans

The programming lessons are structured as two-hour sessions (two class periods) and conducted in two elementary schools: two classes (72 students) in the third grade at A Elementary School and one class (11 students) in the third grade at B Elementary School. To ensure adequate interaction with Robohon, students at A Elementary School are divided into groups of four to five students, while students at B Elementary School worked in pairs. University students assist with instruction and technical support. Pre- and post-surveys are conducted using the three evaluation methods described earlier to assess changes in students' perspective-shifting abilities.

3.1.2 Learning Activities

Robohon installed "Robrick", an app for controlling Robohon with programs, connects to the classroom Wi-Fi router. The Robohon's IP address is assigned within the local network, allowing students to access the Scratch-based programming interface via their tablets' web browsers.

3.1.3 Learning of Programming Concepts

The lesson begins with learning of the three fundamental programming concepts using a flowchart:

- **Sequential Execution:** Commands are executed in order from top to bottom.
- **Iteration (Repetition):** Specific commands are executed multiple times.
- **Branching (Conditional Statements):** Robohon responds differently based on recognized voice input.

First, students program Robohon with simple sequential commands such as "stand up," "say good morning," and "dance." After inputting their code via Scratch, students observe Robohon performing these actions in sequence. Secondly, students are asked to program to repeat a series of movements, such as walking in a square pattern. When they program sequential commands, they realize that the program is not efficient. Then they learn iteration and find it is efficient. Thirdly, to introduce branching logic, students are informed that Robohon has a built-in voice recognition function. The recognized speech is displayed on their tablet screens, allowing students to analyze how Robohon processes input. Students then design flowcharts incorporating conditional statements, where Robohon's response would change based on the recognized input. Using Scratch, they program Robohon to recognize specific voice cues and respond differently based on the command given. Finally, they run the program and observe how Robohon's behavior adapts to different voice inputs.

3.1.4 Physical-Level Learning Activities

To promote perspective-shifting at the physical level, a hands-on activity using the Three Mountains Model is conducted: Miniature Three Mountains Models are placed in each group's workspace.

Robohon is programmed to walk around the models and stop at designated viewpoints. Students are asked whether Robohon should turn left or right to face the mountains correctly. Students are prompted to visualize what Robohon would see from different angles and describe the scenery. Students use a tablet camera to take a picture from Robohon's viewpoint, allowing them to confirm their imagined perspective with an actual image. This exercise encourages students to mentally shift their perspectives to Robohon's viewpoint while refining their spatial awareness and observation skills.

3.1.5 Social-Level Learning Activities

For social-level perspective-taking, a role-playing scenario is introduced where Robohon is portrayed as a character experiencing emotions. A scene is set where "Robohon is squatting alone in a corner of the schoolyard." Students are asked to consider how they might approach Robohon and initiate conversation. Using a flowchart worksheet, students write down different phrases Robohon might recognize and how it should respond depending on the voice input it receives. After completing their flowcharts, students implement their designs in Scratch and test their interactive dialogues with Robohon. This activity encourages students to infer emotions, anticipate responses, and adjust their interactions, accordingly, helping them refine their social perspective-taking skills.

Since the sequential progression from physical-level to social-level learning activities was reconsidered, these activities were conducted simultaneously. The activity to promote third-person role-taking was integrated into the social-level learning activities. The purpose of this study is to assess whether these activities contributed to perspective shifts at the physical and social levels and role-taking abilities of elementary school students.

3.2 Evaluation Methods

To measure the effectiveness of the learning activities, four tasks were used.

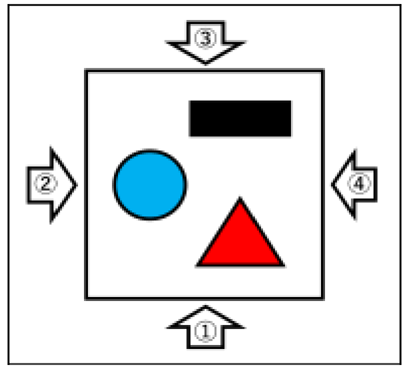
3.2.1 Assessment of Physical-Level Perspective Shifting

- **Task:** Adaptation of Piaget's Three Mountains Problem using a physical model (Figure 1).

- **Method:** Students select a viewpoint from four perspectives (Figure 2) to match what they would see from different vantage points and mark their answers on the answer sheet (Figure 3).

Figure 1: *Three mountain model*

Figure 2: *The four physical perspectives model*



3.2.2 Assessment of Social-Level Perspective Shifting

- **Task:** Role-taking ability assessment using Watanabe's (2001) adaptation of the Wolf's Birthday Present test (Figure 4).
- **Method:** Students listen to a narrated story, evaluate different perspectives, and select responses indicating their understanding of the characters' viewpoints on the answer sheet (Figure 4). (A. lion: Level 1, B. panda: Level 1 to 2, C. koala: Level 2, D. gorilla: Level 0 to 1).

Figure 3: *Answer Sheet*

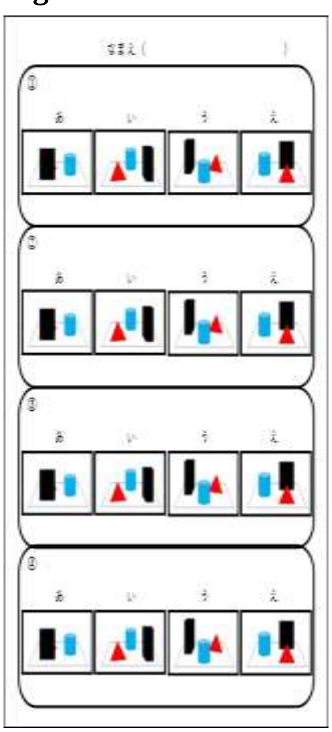


Figure 4: *The Wolf's Birthday Present Test*

3.3.3 Assessment of Third-Person Perspective Shifting

- **Task:** The Sally and Anne test (Figure 5).
- **Method:** Students are asked to infer where Sally would search for an object, measuring their ability to understand others' beliefs.

Figure 5: *The Sally and Anne Test*

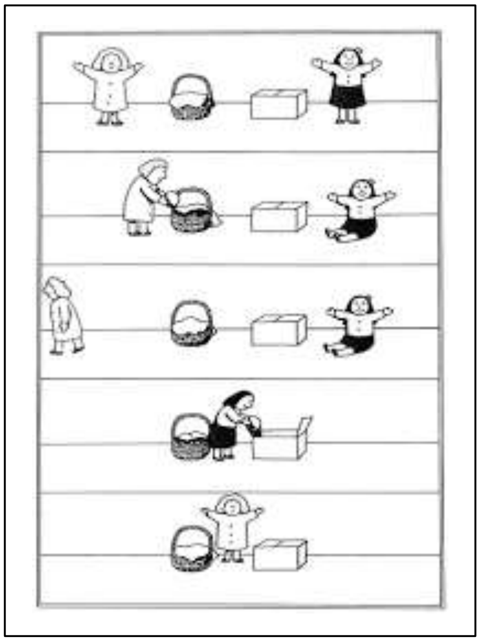
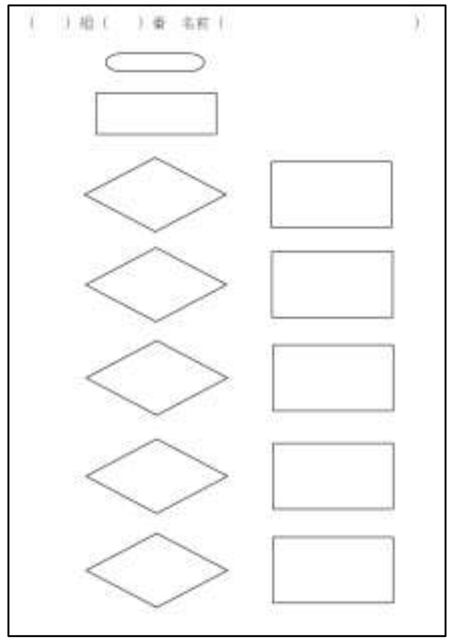


Figure 6: *Flowchart*



3.3.4 Flowchart Task

- **Task:** Students create flowcharts representing interactions between Robohon and users, providing qualitative insight into their reasoning processes (Figure 6).

4. Trial Practice in the Classroom

4.1 Implementation Overview

(1) A Elementary School (72 students, 3rd grade)

- Date: March 2, 2023
- Periods: 3rd and 4th period

(2) B Elementary School (11 students, 3rd grade)

- Date: September 2, 2023
- Periods: 3rd and 4th period

4.2 Classroom Activity Implementation

Students completed three evaluation tasks before beginning the programming lessons (pre-test). Students at A Elementary School were divided into groups of four to five and B Elementary School students worked in pairs, each assigned one Robohon per group/pair. Students learned programming concepts through sequential, iterative, and branching tasks. Students then engaged in physical and social perspective-shifting activities using Robohon. Students debugged and refined their code based on observed outcomes. Following the programming lessons, students took the evaluation tasks again (post-test).

5. Results and Discussion

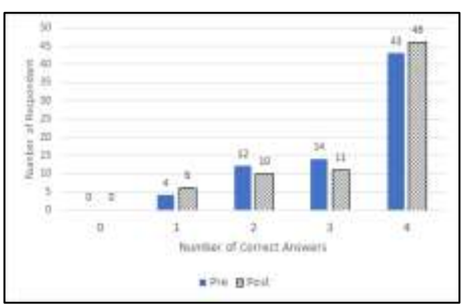
5.1 Survey 1: The Three Mountains Problem

Table 1 presents the changes in response frequencies for choices “あ” through “え” for each question. Correct answers are shaded for clarity. In Q1, the correct response “え” was selected by 98.6% of students in the pre-test and 97.2% in the post-test, indicating minimal change. This consistency may be due to the alignment between the children’s viewing direction and the examiner’s viewpoint.

Table 1: *Frequency of Responses to Survey*

	Q1		Q2		Q3		Q4	
choice	Pre	Post	Pre	Post	Pre	Post	Pre	Post
あ	0	0	1	5	64	57	0	4
い	0	1	4	4	0	10	54	50
う	1	1	53	59	4	2	7	8
え	72	71	15	5	5	4	12	11
null	0	0	0	0	0	0	0	1
Ratio	98.6	97.3	72.6	80.8	87.7	78.1	74.0	68.5

Figure 7: *Number of Correct Answers*



In Q2, correct responses increased from 53 students (72.6%) in the pre-test to 59 students (80.8%) in the post-test, suggesting some improvement. However, in Q3, correct responses declined from 64 (87.7%) to 57 (78.2%), and in Q4, correct responses decreased from 54 (74.0%) to 50 (68.5%). As a result of t-test, neither of these changes was statistically significant at the 5% level.

Figure 7 illustrates the number of correct answers across pre- and post-assessments. In the pre-test, 43 students (58.1%) answered all four questions correctly, increasing to 46 students (62.2%) in the post-test. However, the mean score decreased slightly from 3.31 to 3.18. T-test showed no significant improvement. These results suggest that the programming activities did not lead to a notable enhancement in physical-level perspective shifting.

5.2 Survey 2: Wolf's Birthday Present

Table 2 summarizes response frequencies for each character's idea (A–D). Responses were categorized as negative (-), neutral (±), positive (+), or strongly positive (☆), with the highest response frequencies shaded.

Table 2: *Frequency of Responses to Survey 2*

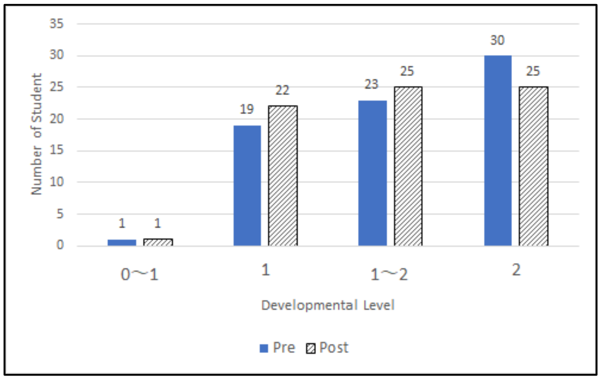
Animal	Mark	－		±		＋		☆		Best	
	Level	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
A. Lion	1	6	3	20	13	36	37	11	20	19	22
B. Panda	Ⅰ～2	26	25	16	13	9	13	22	21	23	25
C. Koala	2	5	9	18	17	22	22	28	25	30	25
D. Gorilla	0～1	42	40	15	14	13	13	3	6	1	1

The most common response for the koala character was "a happy face with a star" (☆), selected by 28 students (38.3%) in the pre-test and 25 students (34.2%) in the post-test. The panda character had the second-highest selection rate, with 22 students (30.1%) choosing it in the pre-test and 21 (28.8%) in the post-test. However, the panda's idea was also rated negatively by 26 students (35.7%) in the pre-test and 25 students (34.2%) in the post-test, indicating divided opinions on its merit.

In the final question, where students selected the animal with the "best idea," the koala had the highest selection rate in the pre-test, but post-test responses showed a closer distribution between koalas and pandas. Some students who had assigned "a happy face with a star" to an animal did not select that animal as the best idea, suggesting possible misunderstandings in the response criteria.

Figure 8 illustrates the developmental levels of role-taking based on these responses. In both pre- and post-tests, Level 2 (second-person role-taking) was the most prevalent, with 30 students (40.5%) in the pre-test and 25 students (33.8%) in the post-test. Given that Level 1 (subjective role-taking) is typically observed in ages 6–7 and Level 2 in ages 8–11, most students (71.6% pre-test, 67.6% post-test) fell within the expected developmental range.

Figure 8: *Development Level*



While there were fluctuations in responses before and after the programming activities, no significant difference (at the 5% level in t-test) was found in role-taking development. Thus, programming education alone did not appear to significantly influence social-level perspective shifting.

5.3 Survey 3: Sally and Anne Test

Table 3 presents the response frequencies for the Sally and Anne test. While there was a slight increase in the number of students who correctly chose “basket” after the intervention, a chi-square test comparing the ratio of basket-to-box responses between the pre- and post-tests found no statistically significant difference. These results indicate that the programming activities did not effectively improve students’ ability to adopt a third-person perspective.

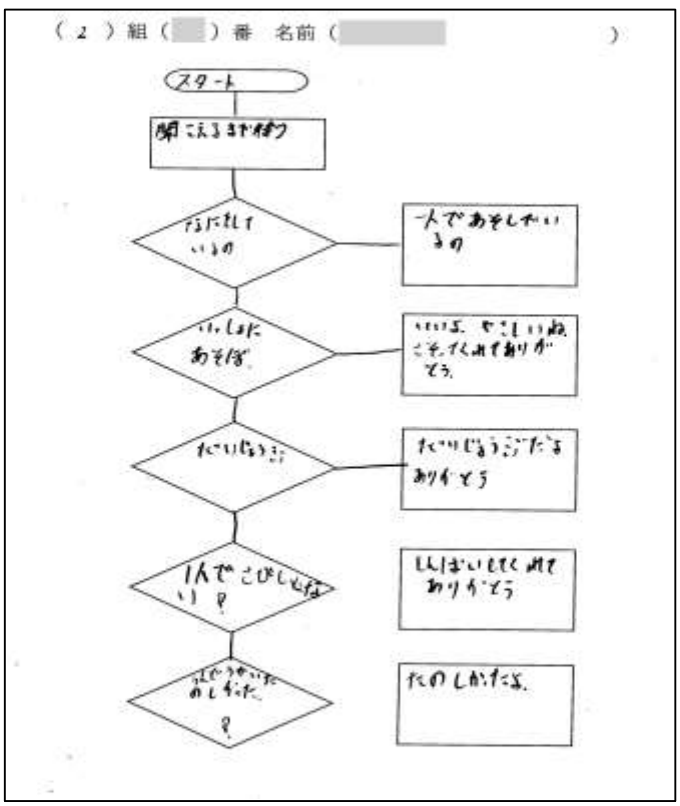
Table 3: *Frequency of Responses to Survey 3*

	Pre	Post
Basket	45	49
Box	28	24
Ratio	61.64	67.12

5.4 Survey 4: Flowchart Analysis

The students' completed flowchart worksheets were collected and analyzed, with a representative example shown in Figure 8. The average number of words written per worksheet was 4.04, suggesting that students engaged in thoughtful consideration of how Robohon should respond to different inputs. Qualitative analysis of the flowcharts indicated that students attempted to structure dialogues based on logical branching. Many responses demonstrated an effort to consider Robohon's viewpoint, indicating some level of role-taking. While these findings do not confirm a direct improvement in role-taking abilities, they suggest that students engaged in perspective-shifting exercises through programming.

Figure 9: *Student's Flowchart*



6. Conclusion

This study trialed programming education as a means of fostering role-taking skills in third-grade elementary school students. Pre- and post-survey results from the Three Mountains Problem indicated no significant changes in students' ability to shift perspectives at the physical level. Similarly, the Wolf's Birthday Present task did not show a notable impact on students' role-taking abilities. The Sally and Anne Task also revealed no substantial improvements in students' capacity to infer others' viewpoints. However, while statistical improvements were not observed in the flowchart analysis, qualitative assessments suggested that students actively engaged with different perspectives while designing Robohon's responses.

Future research should explore refining instructional methods to integrate explicit discussions on role-taking. Longitudinal studies could assess whether extended programming exposure enhances role-taking. Also combining programming with social interaction exercises to improve third-person perspective-taking and adapting programming tasks to include more complex social narratives to further develop role-taking abilities might also yield useful results.

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