Development of Scientific Inquiry Activities for Junior High School Students Using Creation of Quadrupedal Passive Walking Paper Toys

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Abstract. In this study, as the development of scientific inquiry activities using the passive walking toy, we focus on the verification through practice of scientific inquiry activities for junior high school students. In recent years, global issues are piling up and becoming more serious year by year, and the need to develop problem-solving skills is increasing. According to the Courses of Study in Japan call for the enrichment of activities that foster the ability to conduct scientific inquiry. However, there are still problems in developing the ability of scientific inquiry, and it is necessary to experience and develop the ability of scientific inquiry from the early stage of compulsory education. Therefore, a passive walking toy is used as a teaching material that includes scientific inquiry. The following results were obtained through practice with university students using this material. In this study, scientific inquiry activities using the passive walking toy were conducted with junior high school students. The students' responses to questionnaires and reports summarizing the inquiry activity were analyzed qualitatively and quantitatively. The results of the analysis revealed that this activity enables junior high school students to experience a series of scientific inquiry activities and is expected to lead to the development of scientific inquiry skills.

Keywords: Scientific inquiry activity · Passive walking · Science education

1 Introduction

In recent years, global issues are piling up and becoming more serious year by year. In order to develop human resources who can solve these issues, there is an increasing need to cultivate problem-solving skills in school education. According to the International Commission for UNESCO in Japan, education that only teaches knowledge is insufficient to develop problemsolving skills [1]. In order to develop problem-solving skills, emphasis has been placed on the power of scientific inquiry as the ability to use what one knows and can do [2]. The ability of scientific inquiry includes to find problems, to find solutions, and to predict and implement results.

From the above, the Courses of Study in Japan call for the enrichment of activities that foster the ability to conduct scientific inquiry [3]. In Japanese science education, the children acquire developmental skills that lead to scientific inquiry in elementary school

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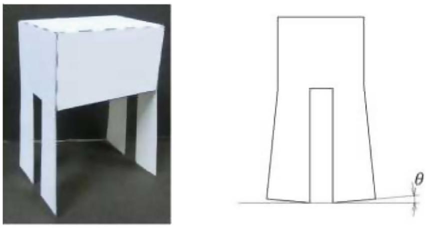


Fig. 1. Quadrupedal Passive Walking Paper Toy

[4]. In high school, "Science and mathematics exploration" was newly established as a school subject that fosters the ability to conduct scientific inquiry [5]. The high school students experience a full range of scientific inquiry activities for the first time. However, it has been suggested that there are some problems with the Japanese scientific education, for example, the ability to aware of scientific questions and to explain the phenomenon scientifically (Ministry of Education, Culture, Sports, Science and Technology, 2019). In addition, teachers do not have a common understanding of scientific inquiry activities, and there is a lack of teaching materials and examples of activities that can be easily implemented [6]. From the above, in order for Japanese children to develop better scientific inquiry skills, it is necessary for them to experience scientific inquiry as early as compulsory education. Furthermore, it is considered necessary to provide teaching materials and examples of activities that facilitate the implementation of scientific inquiry activities.

Therefore, we focused on the passive walking toy that includes the scientific inquiry. The quadrupedal passive walking toy shows in Fig. 1 [7]. A passive walking toy has a simple structure without a motor and battery, and moves using only potential energy on a slope. There are many toys using this principle since old time, as it has been recognized that children are interest in the passive walking. In previous study, we clarified the following by the analysis of the practice using the paper toy [8]. 1) Learners are proactive in doing the inquiry activities using the toy. 2) There are various parameters in the toy that learners can change. In this study, we developed a science inquiry activity using a passive walking paper toy, and the analysis of the practice with junior high school students.we develop the scientific inquiry activities using the paper toy. In the analysis of practice, we will evaluate the reports that students produce at the end of their inquiry activities. We will clarify whether it is possible for junior high school students to carry out the process from setting up the task to writing the report using this material.

2 Practice for Junior High School Students

2.1 Outline of Practice

A total of 50 min classes were held between December 2021 to March, 2022 and 18 junior high school students were participated.

The flow of activities is shown in Table 1.

After building the toy, a "Messaging About" time was set aside [9]. During this time, students observed the toy and its structure, and wrote down their questions and

Table 1. Flow of Activities

Number of lessons	1		2	3	
Activities	Prior learning	Making	Setting the Tasks	Setting up a hypothesis	Experimental plan
	Learning about research ethics	Make a toy according to the production procedure	Conduct free trial activities, extract and describe questions and findings Set issues based on their own questions	Extraction of independent and dependent variables and description of rationale Formulation of hypotheses	Experimental design Description of what to use Setting of modified and fixed conditions Description of measurement methods

Number of lessons	4		5, 6, 7	8, 9
Activities	Evaluation and correction	Learning how to set angles	Experiments and Evaluation and modification	Report writing, evaluation and revision
	Self-evaluation and revision of worksheets	Learning how to set angles using trigonometric ratios	Making a toy for the experiment Conduct experiments according to their own plans Self-evaluate and revise experiments	Create a report Self-evaluate and revise reports

a) Observing the toy b) Measuring the speed c) Shooting the movement

Fig. 2. The states of activity

findings on a worksheet. Next, the students set the problem based on the questions they themselves felt, and set up their own hypotheses and experimental plans. The students conducted the experiments according to their own experimental design and wrote a report at the end. Thus, the entire series of scientific inquiry activities are carried out by the students themselves. Moreover, the inquiry that students conduct is almost the same activity as the research conducted by scientists. This activity was intended to be easily implementable by many teachers. Therefore, by incorporating self-assessment activities at various points in the activity, we hoped that students would understand the content appropriate for scientific inquiry activities.

The students' activities are shown in Fig. 2. Figure 2–1 shows that the students are carefully observing the movement of the toy. During the activity, many students observed the movement of the toy and described the characteristics of the movement as well as the walking distance and time. Figure 2–2 shows a student using a computer to measure time, using free timer software. From Fig. 2–3, we can see that the students are using the computer to take videos. The students were actively using ICT in their activities.

2.2 Analysis Method

The items of the questionnaire administered after the activity are shown in Table 2.

Two questions were asked to clarify whether the students were able to make a walkable toy by themselves and whether students were able to set inquiry tasks based on their own question. For both items, the choices were "1 yes, 0 no."

3 Analysis of Practice

3.1 Analysis of the Questionnaire

From the results of item 1), 16 out of 17 students answered "YES." The fact that almost all the students were able to make a walkable toy indicates that the difficulty level of this toy is suitable for junior high school students. Even the students who were not able to make a walkable toy were able to carefully make the toy and carry out the experiment.

From the results of item 2), we can see that all 17 students responded positively. Although it has been pointed out that Japanese children have problems in recognizing scientific questions, the inclusion of the "Messaging About" activity and the worksheet-based activities allowed the students to set their own questions. The children in Japan were able to set their own issues by themselves.

3.2 Analysis of the Reports

The analysis of the reports prepared by the students revealed the content of possible activities for junior high school students.

[Student A]

Theme: Analysis of the relationship between the angle of the sole of the toy and the position of the center of gravity.

Table 2. The items of the questionnaire

The items
1) Were you able to set an inquiry question based on your own questions?
2) Were you able to set an inquiry question based on your own questions? (Choices: 1 yes, 0 no)

Table 3. Result of the questionnaire

The items	Yes	No
1. Was the toy you made a success in walking?	16	1
2. Were you able to set an inquiry question based on your own question?	17	0

S/he did a study to clarify the relationship between the angle of the sole (see Fig. 1) and the position of the center of gravity. Figure 3 shows how s/he revealed the center of gravity. Since she did not know how to calculate the center of gravity by calculation, she revealed the center of gravity by an experiment in which the toy was suspended by a string from three directions. S/he experimented with toys at 5, 10, and 15°. The results are shown in Table 3. From this experiment, s/he found that the toys with soles of 10 and 15° could not continue to walk. According to his/her report, "Toys with soles of 10 and 15° stopped and stabilized in the tilted position. When the tilted toys were placed on a flat table, the toys with soles of 10 and 15° maintained their tilted state. In this state, the center of gravity was above the foot in contact with the slope (cf. Fig. 4). "Next, s/he experimented with masking tape to lower the center of gravity. In this experiment, s/he succeeded in walking of the toy. From the results of this experiment, s/he concluded that the center of gravity position is involved in the toy's walking (Figure 4).

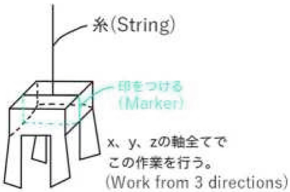
From the above, we can see that s/he feedback the first experiment to the second one and that s/he were able to analyze his/her experiment by applying the learning contents of science and mathematics.

[Student B]

Theme: The study about foot degree of the quadrupedal walking toy.

The purpose of his/her study was to determine the effect of sole angle (cf. Fig. 1) on the walking speed of the toy. S/he experimented with a toy with a modified sole angle and measured walking time and distance. In the first experiment, s/he experimented with the toy with sole angles of 0, 10, and 20°, and measured walking time and distance. The result of his/her first experiments are shown in Table 5. As a result, he clarified the following. The toy with 0 or 20-° foot can never walk. The toy with 10-° foot can hardly walk. S/he wrote that, "The toy with 0-° sole can never swing, and the toy with 10-° sole swing too mach." Therefore, at the second experiment, he used the toy with 3, 5, and 7-° sole. The result of his/her second experiments are shown in Fig. 5 and Table 6. S/he showed result with a box plot that s/he studied in mathematics class. In addition, s/he calculated the walking speed from walking time and distance, and s/he clarified the

(a) The states of clearing the center of gravity



(b) Figure made by student A

Fig. 3. How to clear the center of gravity

Table 4. Result of experiment (made by student A)

	The angle of the sole [degree]			
	5	10	15	10 (with masking tape)
First	O	X	X	X
Second	O	X	X	O
Third	O	X	X	O

O: Success, X : Failure.

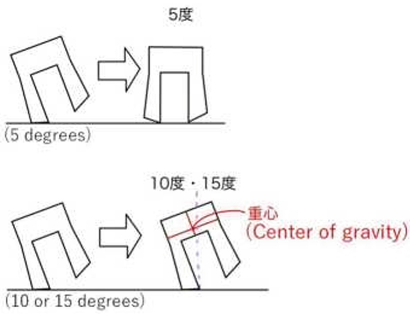


Fig. 4. Movement of toys on the flat desk (made by student A)

Table 5. Result of first experiment (made by student B)

Sole degrees	Average of walking distance [cm]	Average of walking time [s]
0	0	0
10	2.5	8.66
20	0	0

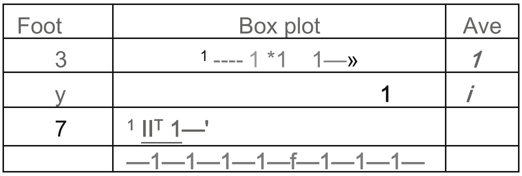


Fig. 5. Result of second experiment (walking distance) (made by student B)

Table 6. Result of second experiment (made by student B)

Student B)		
Sole degrees	Average of walking time [s]	Average of walking speed[cm/s]
3	11.18	0.97
5	27.5	0.65
7	13.19	0.27

connection between the foot degree and walking speed. From the above, we can see that s/he feedback the first experiment to the second one, and s/he was able to clarify the foot angle suitable for walking. Also, we can see that as s/he calculated walking speed and made box plot, it was possible to analyze from multiple angles.

4 Conclusion

This study discusses the development of scientific inquiry activities using a paper quadruped passive walking toy.We conducted this activity with junior high school students and found the following.

- All students were able to make a walkable toy, indicating that the level of difficulty was appropriate for junior high school students.
- All students were able to set their own tasks based on their own questions. The inclusion of the “Messing About” activity and the worksheet-based activities allowed the students to set their own tasks.
- From the analysis of the reports, we could see how the students tried to improve the activity by giving feedback on their failures, how they analyzed the experimental

data from multiple perspectives, and how they applied their knowledge to solve the problems. This activity allows junior high school students to experience a series of scientific inquiry activities, and is expected to lead to the development of scientific inquiry skills.

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