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Research Article

Programming Education Using Maze Exploration for Junior High School Student

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ABSTRACT

With the recent emergence of Amazon warehouses and service robots at airports and hotels, it is believed that we will enter an era in which humans and robots will struggle to coexist. Elementary and junior high school students need robotics education, which sparks their interest at an early stage. In response, higher education institutions are actively working on robot education, but most of them focus on online tracing using microcomputers. In this study, students from a technical college organized a workshop for third-year junior high school students to teach robotics about maze exploration. The lecture was evaluated by means of a questionnaire.

• Introduction

In recent years, robots have been making inroads into society, and it is predicted that an era of coexistence and co-prosperity between humans and robots will arrive in the future. Therefore, it is important to nurture and motivate elementary and junior high school students who are interested in robots at an early stage. In addition to education and research, it is also important for institutions of higher education to contribute to local communities. In addition, cooperative education between elementary and junior high schools is becoming increasingly popular to prevent young people from leaving science and engineering. Table 1 shows related literature.

Tokuyama College (National Institute of Technology) collaborated with elementary schools to plan robot education through a Pupil-centered Robot Contest. The school offers 23 courses, including line tracing, for 1st to 6th grade elementary school students [1]. And Using micron Beauto Racer (Vstone), programming learning curriculum is developed in targets of elementary school students [2].

At Kumamoto College (National Institute of Technology), a robot racer using Arduino was developed as a line-tracing robot for classroom use [3], and there is also a report on embedded system education using line-tracing robots [4].

Shibaura Institute of Technology also uses line tracing for mechatronics education [5]. The Kyushu Institute of Technology holds a junior robot contest using Lego EV3 to conduct line tracing to simulate tomato collection [6]. However, Lego EV3 has a wide variety of sensors, high functionality, and is highly versatile, but very expensive.

As an initiative for maze exploration programming, Nippon Bunri University is conducting a cross-disciplinary university class (robot project) for embedded programming using Lego NXT [7].

There is also a study in which an original microcontroller was produced as a teaching material development for the inverted pendulum [8] for university student.

There is also an effort toward STEAM education using the Beauto Balancer 2 (Vstone) for elementary and junior high school students [9].

We focused on "obstacle avoidance" to introduce junior high and high school students who will survive the

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future AI era to autonomous driving, which will become important. The primary aim was to convey the appeal of the “fusion of robots and programming” to third-year junior high school students, increase their interest and awareness, and use the program to help them choose their future career paths.

In the previous study, a robot programming education using the Beauto Rover (Vstone) was planned as a student-driven activity. The theme was, and as a lesson design, steps to successfully "explore the maze" as the final mission were proposed [10].

In this study, the students led a workshop, and a questionnaire was administered before and after the class to evaluate the usefulness of the lecture.

Table 1 Related research in robot education

Content	Paper	Target audience
Line trace	[1], [2]	Elementary and junior high school students
Line trace	[3], [6]	Junior high and high school students
Line trace	[4]	Technical college
Line trace	[5]	University student
Inverted pendulum	[8]	University student
Inverted pendulum	[9]	Elementary and junior high school students
Maze exploration	[7] [10]	University student Junior high school

Fig. 1 Microcontroller used in this lecture

The remainder of this paper is organized as follows. Chapter 2 discusses the workshop planning and educational materials. Chapter 3 presents the workshop. Finally, Chapter 4 presents an evaluation of the workshop using student questionnaires. Finally, Chapter 5 presents the summary and future tasks.

2. Workshop planning and preparation

2.1 *Student organization*

An organization was created by bringing together students with a strong interest in manufacturing and programming education. The following points were noted at that time:

(A) Since the target audience for the workshop is 3rd -year junior high school students, technical college students in the lower grades (2nd-year students) were needed as much as possible, and 5th-year students in the upper grades were needed to supervise the team.

(B) There is a need for technical staff to deal exclusively with mechanical problems during the lectures.

As a result, three 2nd-year students and two 5th-year students were selected. There will be four classes (the maximum number of participants is 10), with each of the four serving as an instructor. The team comprised teachers, teaching assistants (TAs), and technical staff.

2.2 *Microcontroller used in this research*

The robot adopted Beauto RoverARM (Vstone) (Fig. 1). This microcontroller can be equipped with multiple infrared sensors and controlled using programming. To improve the appearance and organization of the wiring, I designed the body shown in the diagram using SlidWorks and fabricated it by laser processing an acrylic plate.

The language used was visual programming, which is intuitive and easy to understand for elementary and junior high school students to learn the basic movements of the robot (motor drive, one infrared sensor mounted on the head of the mechanism).

2.3 *Maze search programming solution steps*

The basics of robot programming are visual programming, and the operation was checked (Fig. 2(a)).

Step Problems 1-5 (Steps 1-5) for clearing the mission of the final assignment, the “Maze Exploration Program,” were shown as lecture slides. Table 2 lists the important items and points to be remembered for each step.

Problem 1 (Step 1) is to “move forward for one second” and “turn right (turn 90°).” However, we practice the extent to which the robot rotates, relative to the number of rotations and time (Fig. 2(b)).

Problem 2 (Step 2) is an exercise in which Problem 1 is repeated four times, and the students are taught the useful “loop function.” (Fig. 2(c)).

From Problem 3 (Step 3) onwards, there will be driving problems with sensors, and students should take sufficient time to practice problem-solving using the “branching function.” (Fig. 2(d))

Problem 4 (Step 4) involves traveling along a known route. Therefore, the task is to plan a route in advance for obstacles and to create a control program accordingly. The knowledge gained in Problems 1–3 is then employed to create a route freely (Fig. 2(e)).

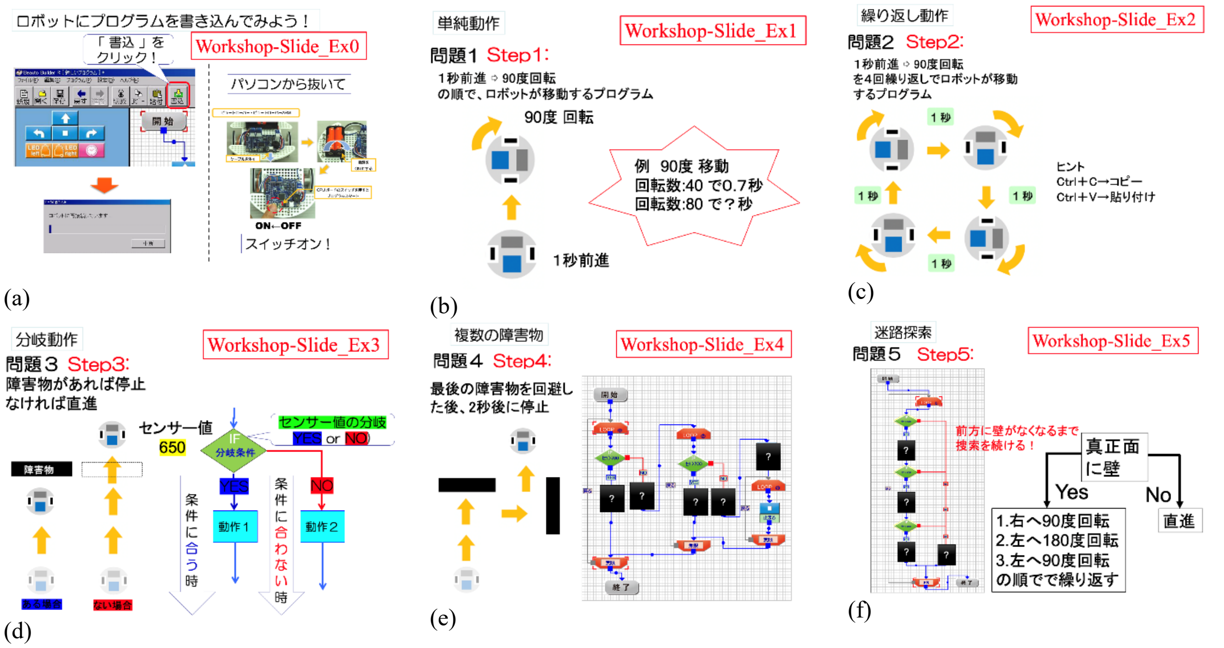


Fig. 2 Steps to explore the maze (a). Basic lecture. (b). Pro-1(Step 1). (c). Pro-II(Step II). (d) .Pro-III(Step III). (e). Pro-IV(Step IV). (f). Pro-V(Step V).

Problem 5 (Step 5) involves running through an unknown maze. Therefore, we need to create a program that not only follows a predetermined route, given the placement of obstacles, but can also handle changes in the placement of obstacles. It must be produced (Fig. 2(f)).

Table 2 Foints to note regarding teaching materials and instruction

	Items	Points to note when teaching
Basic lecture	・How to connected computer and micron and basic motions	
Pro-1 (Step 1)	・Go straight/turn right ・Relationship between rotation speed and turning angle	Help students understand the relationship between rotation speed and time for 90° bending
Pro-2 (Step 2)	Repeat operation	You will be able to use the Loop function
Pro-3 (Step 3)	Sensor and IF function	Be able to use the role of the sensor and the IF function
Pro-4 (Step 4)	Traveling on a known route	Summary of standing still, going straight, and turning left and right (basic driving)
Pro-5 (Step 5)	Traveling through an unknown maze	Understand the difference from driving on a known route

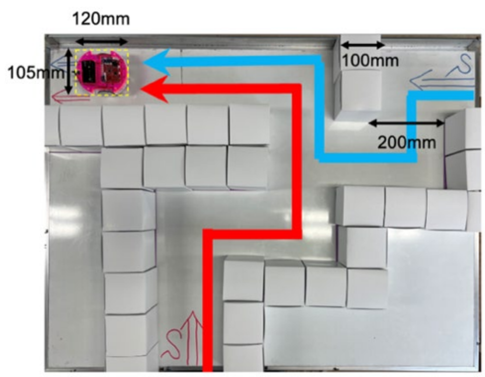


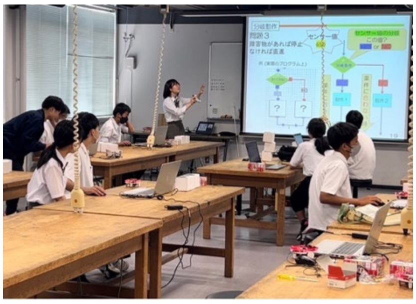
Fig. 3 Maze exploration course

2.4 *Maze size and course*

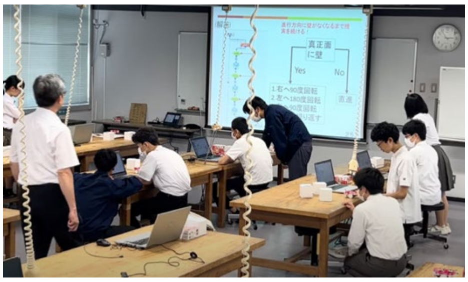
Fig. 3 shows an overview of the maze course. We used cubic boxes with sides of 100 mm for the obstacles and prepared 50 of them. The width of the path through the maze was set to 200 mm. However, it was confirmed that the robot could fit through a 90 mm × 125 mm rectangle. The obstacles could be freely rearranged to suit the level of the participants. The board has squares drawn on it, so even if the placement of obstacles is out of order, you can easily organize them.

- **Workshop**

For the teaching system, the teacher gave a lecture for each problem to explain basic knowledge and provide hints (Fig. 4(a)). Anticipating differences in students' progress, we prepared an individual support system with TAs during the exercise period and encouraged them to solve problems on their own (Fig. 4(b)). The students who solved the final problem, i.e., the maze search program, performed an experimental run with the support of TAs (Fig. 4(c)). Finally, we summarized and conducted a post-event questionnaire.



(a)



(b)

(c)

Fig. 4 Teaching system in the workshop, (a) lecture by students, (b) individual support from teaching assistants, and (c) maze driving test.

- **Questionnaire evaluation**

Table 3 shows the contents of the prequestionnaire and postquestionnaire. Three questions were posed. For each question, a three-point multiple-choice format with scores of 1, 2, and 3 was adopted to measure the level of awareness.

To reduce the burden on participants and ensure a smooth lecture, the show-of-hand method was used (the instructor read out the questions). Data were recorded using video recordings of the lectures and tabulated.

There were 7 participants (A to G) (Fig. 5), 9 participants (A to I) (Fig. 6), 10 participants (A to J) (Fig. 7), and 8 participants (A to H) (Fig. 8) in the 1st, 2nd, 3rd, and 4th sessions, respectively. The results are shown in bar charts for participants A to J; blue and red represent the results before and after the course, respectively. Fig. 9 focuses on the scores for the three questions and shows the average scores for all participants.

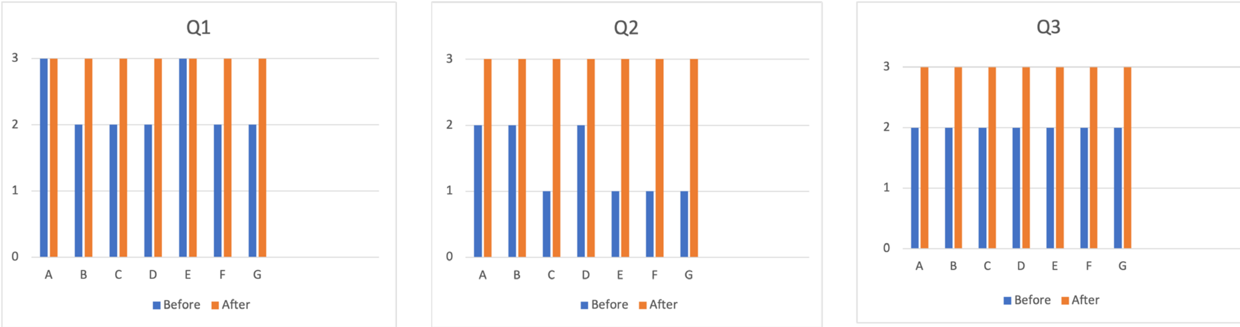
Meanwhile, the prior score for Question II was 1.2 points, indicating that most participants had never heard of obstacle avoidance techniques. However, my post-class score was 2.7 points, so I can say that I understood most of the content after the class.

Furthermore, for Question III, how much did the students understand the theme of this class? The prescore was 1.3 points, but the postscore was 2.1 points, indicating that the level of understanding had improved significantly.

Therefore, this workshop significantly improved the students' awareness of programming.

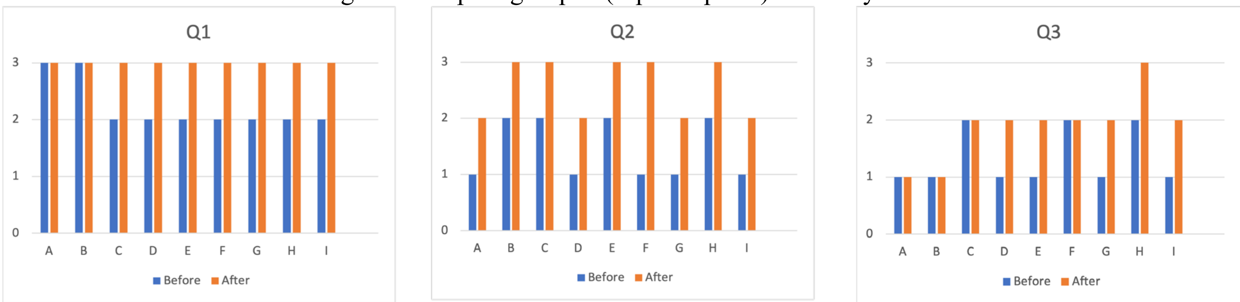
Table 3 Questionnaire content

A: Programming		
Not interested. (1 point)	Average (2 points)	Interested (3 points)
B: Obstacle avoidance technology		
Do not understand (1 point)	I kind of understand it (2 points)	I understand. (3 points)
C: Maze exploration		
Do not understand. (1 point)	I kind of understand it (2 points)	I understand (3 points)



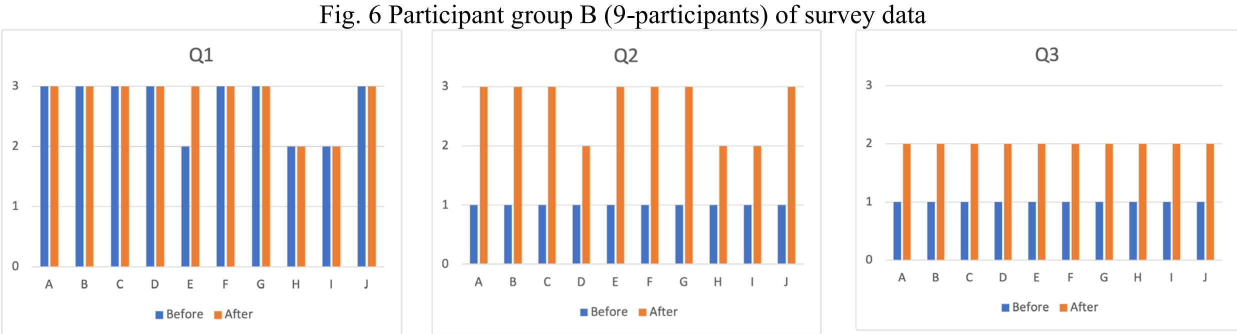
(a) Quation 1 (b) Quation 2 (c) Quation 3

Fig. 5 Participant group A (7-participants) of survey data



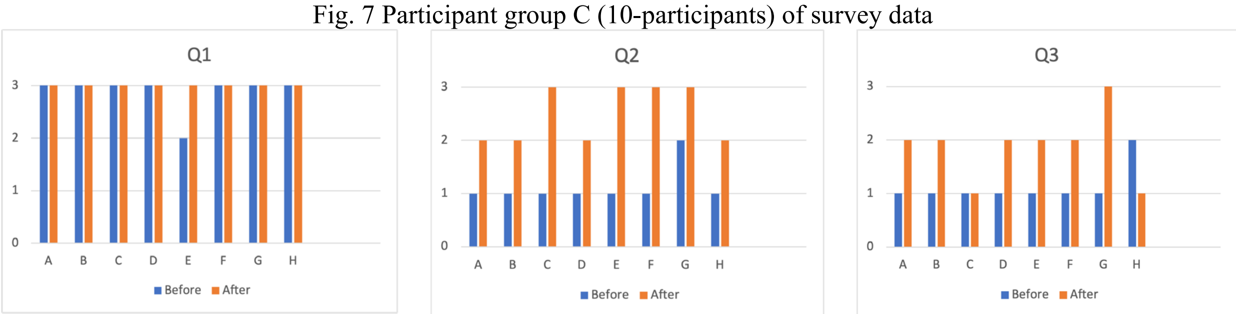
(a) Quation 1 (b) Quation 2 (c) Quation 3

Fig. 6 Participant group B (9-participants) of survey data



(a) Quation 1 (b) Quation 2 (c) Quation 3

Fig. 7 Participant group C (10-participants) of survey data



(a) Quation 1 (b) Quation 2 (c) Quation 3

Fig. 8 Participant group D (8-participants) of survey data

Fig. 9 Average score of participant questionnaire data

- **Conclusion**

In this study, we adopted a microcomputer (equipped with a single infrared sensor on the head) to learn robot programming that even junior high school students can easily handle. We developed teaching materials based on the concept of maze exploration. Furthermore, we held a workshop and evaluated educational effectiveness through pre- and postquestionnaire student (participant) questionnaires. Consequently, we found that the workshop had a significant effect on changes in interest and awareness.

In this study, we focused on simple maze search. However, in a future project, we plan to increase the number of sensors to three and develop teaching materials that will allow students to learn more complex and highly accurate maze searches.

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