SUGISAKA MASANORI

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Research Article

Robotics Education for Elementary and Junior High School Students Using Beauto Balancer

Youta Takano[1], Kenji Kimura[2]
[1]*Belair-systems, Inc, 20-8 Hina-minami-machi, Okazaki-shi,Aichi,444-0915, Japan*
[2]*Department of Control Engineering, National Institute of Technology, Matsue College, 14-4 Nishi-ikuma-cho, Matsue-shi,Shimane,690-8518, Japan*

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ABSTRACT

In recent years, it has become necessary to use programming in controlling robots. However, there are few educational materials for elementary and junior high school students to understand and be interested in the concepts of programming and control engineering. In the previous study, we planned an educational program using "Beauto Balancer2," an educational robot developed by Vstone Corporation, to explain the mechanism of inverted control and to allow students to actually touch the robot, so that they can experience various technologies including control engineering and become interested in mathematical subjects in general, which are the basis of these technologies. The educational program was planned so that students could experience various technologies including control engineering through hands-on experience with robots and develop an interest in mathematical subjects in general. In addition, a craft class was conducted and evaluated using the results of questionnaires. In this study, mock classes were conducted using the existing software for educational robots created in the previous study, and comparisons and verifications were made by focusing on three persons with similar characteristics.

1. Introduction

The Ministry of Education, Culture, Sports, Science and Technology (MEXT) has made programming education mandatory for elementary and junior high schools starting in FY2021 [1]. In the same year, MEXT also recommended STEAM education [2].

Kato conducted an objective verification of educational effectiveness through robot building and robot contests. Here, as an objective method of measuring effectiveness, criteria for behavior evaluation were established and implemented, and the behavior of the subjects was evaluated by TAs [3]. This study cites education in the setting of a robotics class for elementary and junior high school students.

Kawakita used a technique called jigsaw codes to visualize programming processes and thoughts, and analyzed their tendencies [4]. Jigsaw codes are completed by rearranging randomly arranged lines of code into an order that the player (programmer) considers appropriate.

Hirata developed an experimental teaching material that enables students to identify control objects in both the time and frequency domains and to design control systems while considering the relationship between them [3]. This teaching material is intended for beginning students of control engineering.

Kimura designed a lesson design for elementary and middle school students using Vstone's "Beauto Rover" and genuine software, and executed a mock class [5]. The focus of the mock class here was on the participants' thinking about how they would complete the assigned mission.

In the previous study, we used the educational robot "Beauto Balancer2" (Fig. 1, hereinafter referred to as "the robot") developed by Vstone Corporation (hereinafter referred to as "Vstone") to explain the mechanism of inverted control and to let the participants actually touch the robot, aiming to help them understand the concept of control engineering. The educational program was

Corresponding author's E-mail: y8otaman@gmail.com, k-kimura@matsue-ct.jp

planned so that the students could experience not only control engineering but also basic programming techniques, etc., and become interested in mathematical subjects in general, which are the basis of control engineering. In addition, we conducted an actual craft workshop and evaluated the results of the questionnaire survey [6].

In this study, using the existing software for educational robots created in the previous study, classes were planned and implemented so that elementary and junior high school students would be interested in a wide range of fields and be challenged in their learning. The evaluation method was the same as in the previous study, using a questionnaire. In addition, we focused on three students in the same grade at the same school for comparison.

Fig.1 Robot used in this project

2. Lesson Content

We designed an educational design consisting of a class and software, aiming to have the participants understand the concept of control engineering, experience basic programming techniques, etc., and become interested in mathematical subjects in general, which are the basis of control engineering. Based on this design, a mock class was conducted. The instructor was assumed to be the author, and the number of participants was limited to five. A teaching assistant (TA) was also provided. The classes were held as part of a craft class sponsored by the National Institute of Technology, Matsue College, and the participants were recruited from the general public. The experimental dates are shown in Table 1. Fig. 2 shows a scene of the experiment.

The simulation consisted of four steps. Step.4 is only a supplemental step and was excluded from the evaluation.

Step.1 Experience 1 (operation tutorial)
Step.2 Classroom lecture (explanation of operation)
Step.3 Experience 2 (Problem Solving)
Step.4 Classroom lecture
(supplementary explanation)

Fig.2 View of this experiment

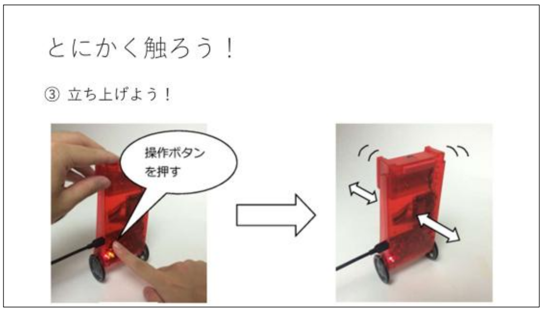

Fig.3 Slide showing how to use (Step.1)

Each step is presented in turn.

Step.1Experience 1 (Operation Tutorial)

The use of Beauto Balancer 2 and the genuine software were explained, and the participants experienced the sensation of Beauto Balancer 2 in operation (Fig. 3). The aim here was to make the participants feel familiar and comfortable with the robot. In doing so, the subject was asked the question, "What is gain?" and asked them to answer the question while touching the genuine software (Fig. 4). We also gave them hints as necessary (Fig. 5), because we thought it would be very difficult for elementary and junior high school students to derive the answer as it is. Incidentally, we have tried to refrain from theoretical discussions here.

Fig.4 Questioning (Step.1)

Fig.5 Hints for asking questions (Step.1)

Table 1 Schedule of experiments

Experiment name	Date	participant
control experiment	August 6, 2023	3 persons
original experiment	December 16, 2023	4 persons
Positive experiment*.	December 24, 2023	4 persons

*Since the number of participants wishing to participate in this experiment far exceeded the maximum number of participants, the same content as in this experiment was used. In addition, three eighth graders from the same school participated in the course at that time.

Step.2 Classroom lecture (explanation of operation)

The concepts of mathematics and physics and control engineering were explained to the subjects in a nutshell. First, basic knowledge and concepts of mathematics and arithmetic (functions, derivatives and integrals) were explained; Fig. 6 shows a slide explaining integrals. Next, velocity was explained as a fundamental concept in physics. Fig. 7 shows a slide explaining velocity, and Fig. 8 shows a slide explaining acceleration. Finally, the two contents were used to explain how to combine them into a single concept; Fig. 9 shows how this was done, with the slide explaining velocity and acceleration (physics) using knowledge of calculus (mathematics). When explaining with such slides, we added movement to the slides using animation and other techniques. This ensures visual clarity.

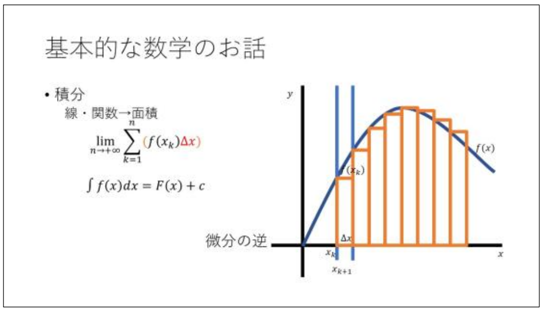

Fig.6 Explanatory slide for integration (Step.2)

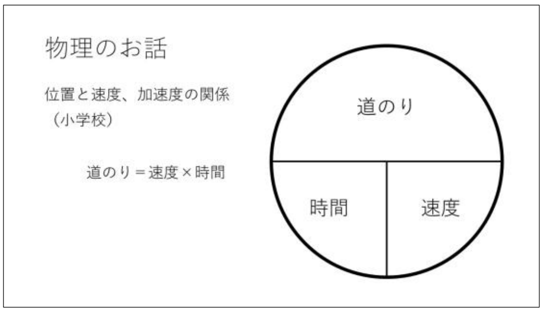

Fig.7 Slide explaining speed (Step.2)

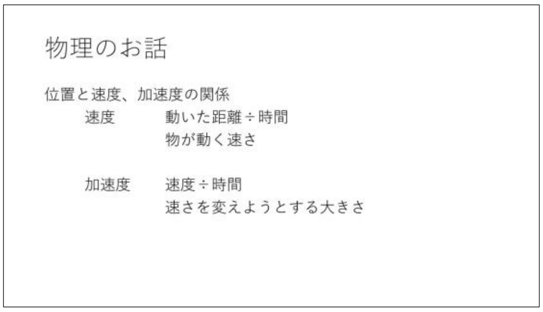

Fig.8 Slide touching acceleration (Step.2)

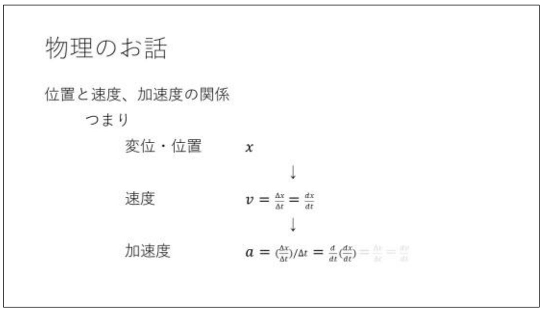

Fig. 9 Explaining velocity and acceleration with knowledge of calculus

Step 3 Experience 2 (Problem Solving)

First, the answers to the questions posed in Step.1 were revealed. Next, the cloth was distributed and the gain was adjusted, and the subject was given the task of making Beauto Balancer2 stand inverted in a stable manner. The subjects then defined the movements they wanted the robot to perform and asked it to execute them in sequence (Fig. 10). In the control experiment, the subject manually controlled the robot by writing out the movements on a special form using the original software (Fig. 11). In the main experiment and the follow-up experiment, we used our own software. Fig.12 shows the participants thinking about how to solve the problem using the Scratch sprint, and Fig.13 shows the actual problem solving using the home-made console application.

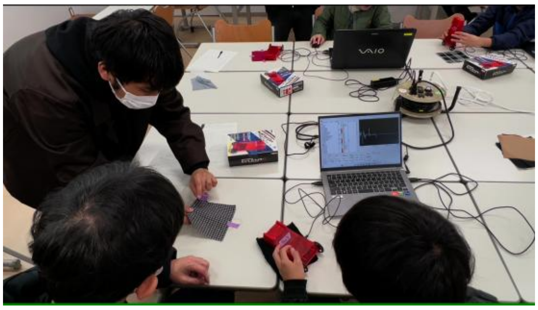

Fig.10 Subjects working on problem solving (Step.3)

Fig.11 How to solve in a control experiment (Step.3)

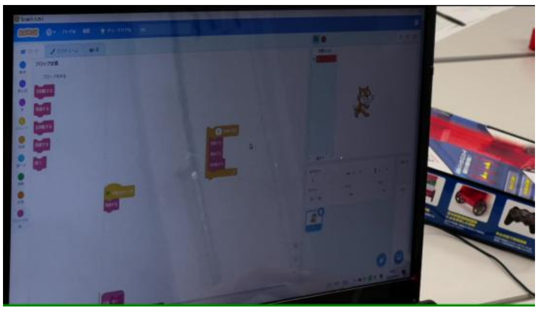

Fig.12 Thinking about how to solve a problem (Step.3) with home-made software (Scratch Spectrum)

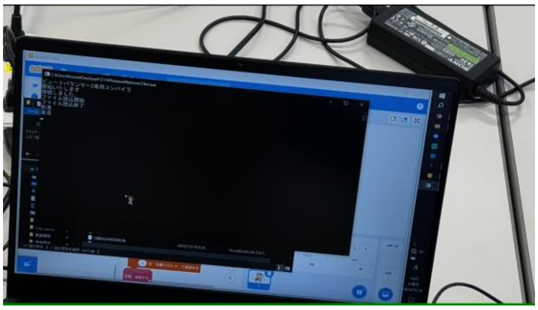

Fig.13 Actual problem solving with home-made software (console application) (Step.3)

Step. 4 Classroom lecture 2 (supplementary explanation)

As one example of a technology that improves and benefits as control engineering research advances, we described a pendulum-type car body tilting device on a railroad (Fig. 14 and Fiq. 15). Various express trains in the San-in region, including Shimane Prefecture, are equipped with various types of car body tilting devices, which were adopted because it is easy to explain comparisons between generations; Figs. 16 and Fig. 17 illustrate the changes in behavior with and without car body tilting devices through full views of each train taken by the author.

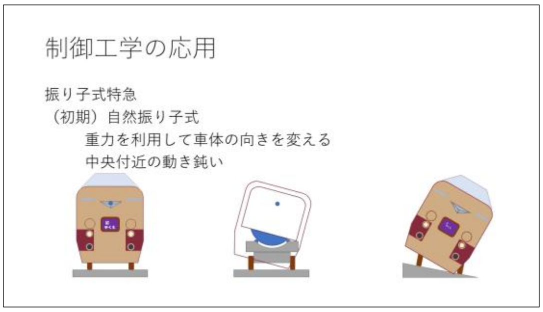

Fig.14 Explanation of body tilting device (1) (Step.4)

Fig.15 Explanation of body tilting device (2) (Step.4)

Fig.16 Front view of a car equipped with a body tilting

Fig.17 Front view of a car without body tilting device

3. Lesson Content

The robot used in this study comes with the original software (Balancer 2 Programmer). However, in order to achieve the goal of having the robot embody the behavior envisioned by the subjects, it is necessary to develop functions that are not included in the stock software. Fig. 18 shows the overall diagram of the system.

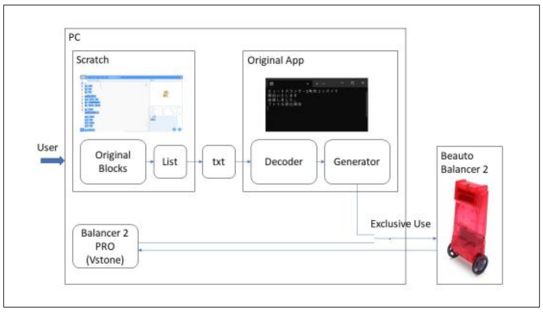

Fig.18 Overall diagram of home-made software system

We describe the overall system flow, its use, and how it works. First, a txt file was generated from the visual programming editor (Fig. 19). The students were then asked to generate the list using the function to output the list in a txt file. Next, ask participants to set up the communication software. To reduce the burden on the participants, we implemented the software in such a way that it could be automatically loaded and executed by simply clicking on the application and having it open. When the communication software is opened, USB HID communication is automatically established and the txt file is read. At this time, we designed the software to read the txt file sequentially and issue communication commands according to the contents of each line (Fig. 20). Although the home-built software and the genuine software coexist, the operation commands to the robot are exclusive.

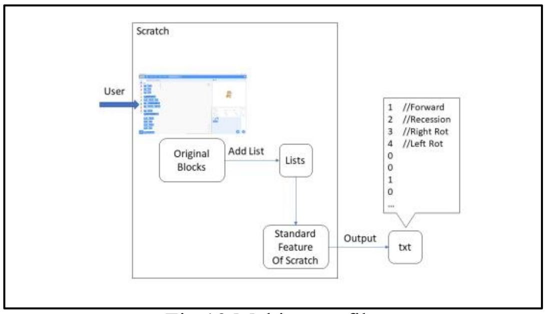

Fig.19 Making txt file

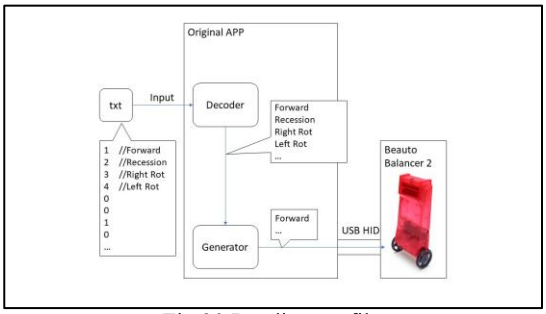

Fig.20 Reading txt file

4. Evaluation by questionnaire

4.1. Evaluation Method

In order to test the effectiveness of the program, a pre- and post-class questionnaire was administered to the subjects. Subjects were asked 5 questions before and after each class. The questionnaire was given on a 5-point scale, with the higher the number, the more positive the evaluation. The contents of the questionnaires are shown in Table 2 for the pre-lesson and Table 3 for the post-lesson. The purpose of the pre-class questionnaire was to gauge the students' awareness and interest before the class, and the post-class questionnaire was to see changes in awareness and interest after the class.

Table 2 Pre-Class Questionnaire

Q1 Do you like mathematics?				
1 (No.)	2	3	4	5 (Yes)
Q2 Do you like science?				
1 (No.)	2	3	4	5 (Yes)
Q3 Can you visualize the control?				
1 (No.)	2	3	4	5 (Yes)
Q4: Are you concerned about what math and arithmetic learned in school is used for?				
1 (No.)	2	3	4	5 (Yes)
Q5 What science is used for in school Are you curious?				
1 (No.)	2	3	4	5 (Yes)

Table 3 Post-class questionnaire

Q1: Have you developed an interest in mathematics?				
1 (No.)	2	3	4	5 (Yes)
Q2 Were you interested in science?				
1 (No.)	2	3	4	5 (Yes)
Q3 Did you have an interest in control engineering?				
1 (No.)	2	3	4	5 (Yes)
Q4 Did you want to know more about what math and arithmetic is used for in school?				
1 (No.)	2	3	4	5 (Yes)
Q5 What is the science you learn in school used for? Do you want to know more about it?				
1 (No.)	2	3	4	5 (Yes)

4.2. Result

Fig. 21, Fig. 22, Fig. 23, and Fig. 24 show the average of the results of the pre- and post-class surveys at each session, respectively. The horizontal axis represents each question in the questionnaire, and the vertical axis represents the average of the results of the responses. In addition, Fig. 24 shows the resultant average of the sum of the results from each experiment.

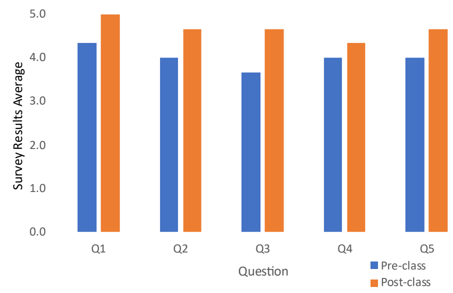

Fig.21 Average scores of questionnaires in control

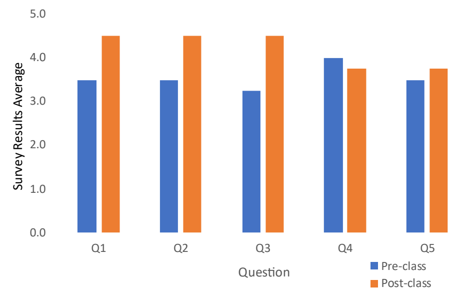

Fig.22 Average score of the questionnaire in this

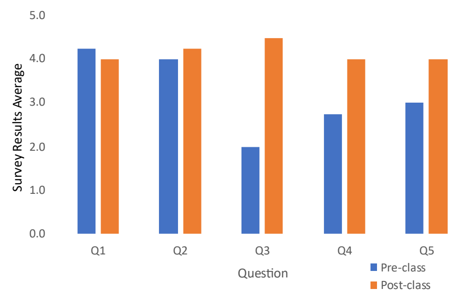

Fig. 23 Average scores of questionnaires in the follow-up

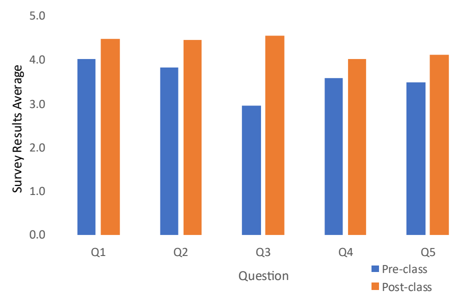

Fig.24 Score average of the questionnaire for the whole

4.3. Discussion of Verification Result*s*

As shown in Fig. 21 and Fig. 22, the number of participants decreased or increased only slightly in some items. However, in the mock class conducted in this study, we were fortunate to be able to gather three students in the same grade at the same school. Based on this, we focus on Q4 and Q5 of the post-class questionnaire in Fig. 23. As Fig. 24 shows, we believe that the direction of the educational design was correct.

In the free-entry column of the questionnaire, there were negative comments such as "I could not understand much," positive comments such as "It looks difficult, but I think I would enjoy it if I understood it," and a note that the participants became interested in technical colleges through the mock class. Reading these comments, we believe that there are several issues to be addressed. For example, the content of the mock class may have been too specialized for the participants. This is one of the issues. We believe that changing the subject matter to a more generalized content may have changed the results somewhat. We believe that changing the subject matter to a more generalized content may have changed the results somewhat.

The self-made program used in the previous study and the current study was designed to consist of three pieces of software in order to introduce the mechanism in an easy-to-understand manner. However, some participants and their parents commented that the program was inconsistent and difficult to understand. Based on these comments, we decided that it would have been better to integrate them into a single program. We believe that this is a good idea. The solution to this problem is to create a C language application. However, some of the participants in this study were interested in the mechanism, so when creating a new version in the future, application specifications that make the mechanism easy to understand should be defined with this in mind.

5. Conclusion

In this study, mock classes were conducted using the software and instructional design produced in the previous study and validated by focusing on subjects with similar characteristics. The results of the validation showed that mathematical interest was improved. It was also hypothesized that the designed educational design and the content of the mock class may have been misaligned with the objectives of the study.

We believe that in the future, a larger number of subjects should be prepared and grouped together to conduct the survey in a group setting. We also believe that the content of the educational design and mock classes should be scrutinized to make the content more general.

Acknowledgements

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Authors Introduction

Mr. Youta Takano

He was student at the Department of Control Engineering, National Institute of Technology, Matsue College until March 2024. His research interests include educational materials for robots and STEM education. Now, he is working at Belair-systems,Inc.

Dr. Kenji Kimura

He is Associate Professor at the Department of Control Engineering, National Institute of Technology, Matsue College, and a Visiting Associate Professor at Chuo University. He received his ME (mathematics) from Kyushu University in 2002 and his PhD (engineering) from the Kyushu Institute of Technology in 2020. His research interests are spherical mobile robots.