Design and Software Production of Robotics Educational Design for Elementary and Junior High School Student

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Abstract

The Ministry of Education, Culture, Sports, Science and Technology (MEXT) has been promoting cross-curricular learning including STEAM education in its educational policy for 2021. The purpose of this study is to have students experience not only control engineering but also basic programming techniques, and to have them become interested in mathematical subjects in general, which are the basis for control engineering. The educational design and accompanying software were designed using Beauto Balancer2 (Vstone) educational robot and Scratch, a visual programming editor developed by the Scratch Foundation. In addition, workshops were conducted, and the lesson design was evaluated by a questionnaire.

Keywords: Robot education, Control engineering, Visual Programming, Beauto Balancer

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 2021. The purpose is to develop children's programming abilities, discover their hidden potential, and create opportunities for them to play an active role in society in the future [1].

In addition, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) promotes STEAM education and other cross-curricular learning to apply learning in each subject and other areas to discovering and solving problems in the real world. This is aimed at fostering problem-solving skills that transcend subject boundaries [2].

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.

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 [4]. This study cites education in the setting of a robotics class for elementary and junior high school students.

In recent years, it has become necessary to use some form of programming in controlling robots. However, there are few educational materials for elementary and middle school students that can help them understand and become interested in programming and control engineering concepts. There have been no control engineering-related studies targeting elementary and middle school students or aiming to educate them about new concepts through robotics.

In this study, we will develop extensions to existing educational robots and plan lessons that will enable elementary and junior high school students to become interested in a wide range of fields and challenge themselves to learn. The robot used in this study, "Beauto Balancer2 (Vstone)," is a teaching material aimed at learning control. Therefore, it is necessary to develop new software to use it as a teaching material for programming classes.

2. Creation of home-grown software

2.1. *Examination of specifications for home-grown software*

In this study, Beauto Balancer 2 (Vstone) will be used.

Beauto Balancer 2 comes with the factory software (Balancer 2 Programmer).

The objectives sought for the home-made application used in this study are as follows.

- To have the robot embody the behavior envisioned by the subject.
- The difficulty level of the application should be such that elementary and junior high school students can operate it without difficulty.
- Use of libraries (written in C) provided by Vstone

To achieve these goals, we have defined the functions to include or coexist with the functions of the original software (Balancer 2 programmer) and to introduce the concept of visual programming so that elementary and junior high school students can easily operate the software.

To achieve this, the following three compositions and description methods were considered.

A Desktop application only (written in Python)
B Console application (written in C)
C Scratch script + console application.
+ Genuine software (written in C)

Table 1 Study table for the software specification

	advantage	disadvantage
A	Use of external libraries facilitates UI tuning	The stock library needs to be re-written in advance. Even if the library is ported to Python, there is no guarantee that the serial communication system will work properly.
B	User operation unit (so-called front end) and the language of the internal processing part (i.e., the bag-end) Uniformity is possible, allowing for flexible design and description.	The nature of console applications limits UI tuning. High degree of difficulty in introducing visual programming concepts.
C	Troubleshooting is easier because software is created or diverted by dividing functionality.	Software tends to be somewhat cumbersome to configure, as software is divided by function, which is less consistent than other proposals

Table 1 shows the results of the study and review of the specifications (A, B, and C). Initially, we adopted proposal A, giving priority to the user interface (UI). However, the communication problems could not be solved, and the development process would have been too large, so we gave up on it. Next, they decided to adopt proposal C and develop it in earnest, as it was judged to be more effective in terms of man-hours among the three proposals.

2.2. *Software Development*

As a result of the study in section 2.1, we adopted C and produced two applications. The overall system configuration and process flow are shown in Figure 1. The first is a visual programming editor produced using Scratch 3.6. The second is a communication software written in C.

The flow of the entire system, its usage, and its structure are described. First, a txt file was generated from the visual programming editor, and using Scratch's original block definition function, a block was created to add a string to the list according to the contents of the action (e.g., forward, stop). After the participants created their own actions, we had them generate them using Scratch's txt file output function for the list contents.

Next, we asked participants to start up the communication software. To reduce the burden on the participants, we implemented the software so that it could be automatically loaded and executed by simply clicking on the application to open it.

When the communication software is opened, it automatically establishes USB HID communication and reads the txt file. At this time, we designed the software to read the txt file sequentially and issue communication commands according to the contents of each line.

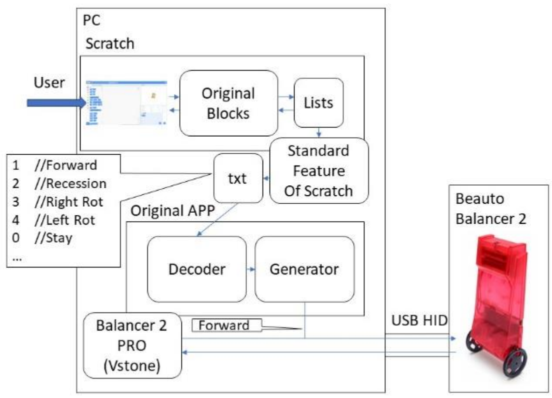

Figure 1 Overall system design

3. Mock Class for Experiments

3.1. *Design of mock class*

A mock class was conducted for elementary and junior high school students (hereinafter referred to as participants). The evaluation was based on the results of the participants questionnaires. The dates of the experiments were as follows Table 2.

Table 2 Planning mock classes

Date	participant
December 16, 2023	4 persons (Breakdown: Fourth grade. 2 students, (one each in sixth grade and eighth grade))
Title. Student-centered lectures and hands-on practice ♪ ～Let's feel mathematics, physics, and control by using butte balancer! ～	

The author was the instructor and one teaching assistant (TA), and the maximum number of participants was set at five. Each mock class was held as a part of a craft class hosted by the school, and participants were recruited from the public through posters distributed to elementary and junior high schools in Shimane Prefecture. The aim of the classes was to encourage students to become interested in mathematics, physics, and all other fields by experiencing the mechanisms that make objects move as desired. The mock class consisted of three steps (Step.1-3).

Step.1 "Let's get used to the robot! "
After giving the students the course materials and explaining how to use the robot and its software, we ask them to touch the robot. Since this is the first time for the participants to touch the machine, we ask them to touch it for the time being to familiarize themselves with it. At this point, we ask them the question, "What is gain? and asked them to answer the question while touching the genuine software. Figure 2 is a slide showing how to use Beauto Balancer 2.

Figure 2 Slide of Class Step 1

Step.2 "Let's feel physics and mathematics! "
Next, mathematics, physics, and control engineering were explained to elementary school students in an easy-to-understand manner using specific examples. At first, basic knowledge and concepts of mathematics and arithmetic (functions, derivatives, and integrals) were explained as necessary knowledge to explain physics concepts. Figure 3 shows a slide explaining integration.

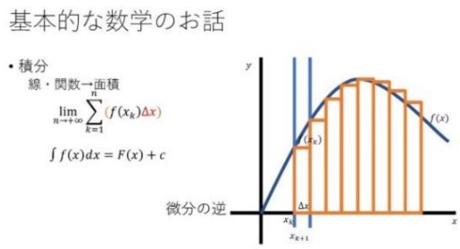

Figure 3 Slide of Class Step 2

Step.3 "Move the robot as you wish! "
We defined the movements we wanted the subjects to perform with the robot and asked them to perform them in sequence. This was done using special software. The explanation was given while displaying the Scratch screen Figure 4.

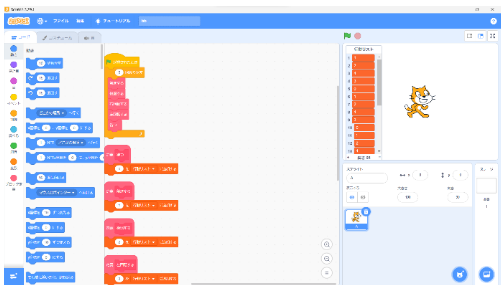

Figure 4 Demonstration of Class Step 3

3.2. *Evaluation of mock class*

To test the effectiveness of the program, a pre-class questionnaire and post-class questionnaire are 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. Table 3 shows the contents of the pre-lesson questionnaire and Table 4 shows the post-lesson questionnaire.

Table 3 Pre-Class Questionnaire

Q1: Do you like mathematics?
Q2: Do you like science?
Q3: Can you visualize the control?
Q4: Are you concerned about what math and arithmetic. learned in school is used for?
Q5: Wha science is used for in school. Are you curious?

Table 4 Post-Class Questionnaire

Q1: Have you developed an interest in mathematics?
Q2: Were you interested in science?
Q3: Did you have an interest in control engineering?
Q4: Did you want to know more about what math and. arithmetic is used for in school?
Q5: What is the science you learn in school used for? Do you want to know more about it?

Figure 5 shows the results of the questionnaire. The horizontal axis represents each question 1-5 in the questionnaire and the vertical axis represents the average of the response results.

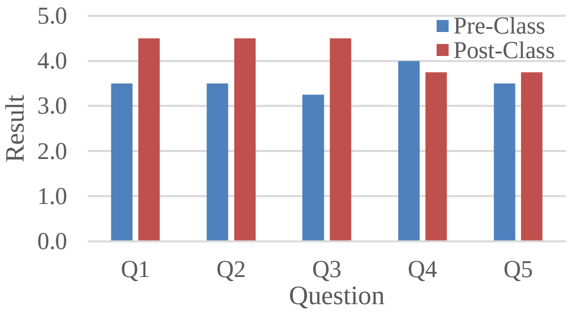

Figure 5 Questionnaire results

3.3. *Discussion of Verification Results*

From Figure 5, the percentage increase in the survey results was calculated and is shown in Table 5. As a result, there is a large increase in some areas. However, Q4 can be taken as showing a decrease.

Table 5 Percentage increase in survey results

	Q1.	Q2.	Q3.	Q4.	Q5.
Rate of increase [%]	29	29	39	- 6	7

Due to the nature of the mock classes held this time, it is difficult to conduct a long-term survey such as a follow-up survey, and the shortcoming is that it is inevitably a short-term survey. In addition, because the recruitment method was open-ended, the results were likely to be influenced by the characteristics of the subject population. For example, if the subjects were junior high school students planning to take entrance exams to difficult-to-enter private high schools, the results of the survey would have changed significantly. Therefore, it is necessary to gather subjects with similar characteristics and ages, and to conduct long-term observation using their parents' and academic records.

4. Conclusion.

In this study, we developed software for robot education for elementary and junior high school students and planned and verified mock classes. The results of the verification showed that the level of interest and concern increased.

In the future, we plan to conduct mock classes with subjects with similar characteristics. In addition, we plan to conduct a long-term post-lesson survey.

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