Classroom practices of low-cost STEM education using scratch

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Abstract

Science, Technology, Engineering, and Mathematics (STEM) education is spreading in some countries. In Japan, it is hoped that STEM education is incorporated into school classes. STEM education is sometimes incorporated experimentally in school classes. It’s not performed in every elementary school yet. STEAM education usually uses robots and the equipment costs money. Only some teachers who get the equipment can perform STEM education classes. Therefore, I would like to propose a low-cost STEM education. In late years, I practiced some elementary school classes using Scratch. Scratch is a useful tool for programming education. I think that Scratch can also be used for STEM education. My proposed low-cost STEM education uses Scratch. In this paper, I show how to use Scratch in STEM education. Scratch can control drones and mobile robots. Low-cost drones and mobile robots are also present. I propose a class that combines this equipment and Scratch. It is also possible to conduct STEM education classes with Scratch alone.

Keywords: Classroom, Low cost, STEM education

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INTRODUCTION

The STEM education of Japan is behind schedule compared with other advanced countries (Omori, Isobe, & Yamazaki, 2016). Japanese Ministry of Education has ordered to teach programming education in elementary school by 2020. It is requested to embed a way of thinking of programming in the subject which already exists. However, teachers belonging to elementary schools are currently in trouble. In particular, liberal arts teachers do not know how to teach programming.

Therefore, I have been practicing classes in elementary school many times in the last few years. These classes use Scratch or JavaScript. Scratch is a visual programming tool that is easy to handle for elementary school students. Scratch, which reads expanded blocks, can also control drones and mobile robots. I think Scratch can be used for STEM education.

This paper shows how to use Scratch in STEM education.

STEM EDUCATION USING MOBILE ROBOTS

Old Style

I think the most famous mobile robot is a LEGO robot. LEGO MINDSTORMS Education EV3 is widely sold. However, it is expensive. The basic set is sold in Japanese yen at 57780 yen (USD 547). It is too expensive to be used in class at the rate of 1 unit per person. In the class practice, I use it at the rate of 1 unit per 6 or 7 people. It is a problem that children who do not try to touch actively appear in group activities.

In the class practice, the task of tracking on the thick black line is often given. The LEGO robot turns right when it moves from the black area to the white area, and turns left when it moves from the white area to the black area. The LEGO robot zigzags along black and white borders. The next task is to go ahead of the area between the blue and red lines. The LEGO robot turns right when it moves from the white area to the blue area, and turns left when it moves from the white area to the red area. After putting an obstacle between the blue and red lines, the
LEGO robot goes ahead avoiding it. These tasks are very good exercises to challenge children through trial and error.

**New Suggested Style**

LEGO robots are expensive, so I suggest cheaper robots. PROTCH (Yamazaki, 2019), which is created by Yamazaki Corporation (http://www.yamazaki-kk.com), is a cheaper robot. The robot image is shown in Figure 1. It is sold in Japanese yen at 3500 yen (USD 33). It has two touch sensors, two light sensors, two (Light Emitting Diodes) LEDs, one buzzer and two motors. Arduino board is included in PROTCH. ProtchEditor can program the movement of PROTCH. Its display image is shown in Figure 2. Protch Editor was created by Massachusetts Institute of Technology (MIT) and is based on the Scratch 2.0 Offline Editor. It uses Adobe AIR and Arduino IDE.

![PROTCH Image](image1)

**Figure 1. An image of PROTCH**

![Protch Editor Image](image2)

**Figure 2. A display image of protch editor**

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**STEM EDUCATION USING ONLY SCRATCH**

**Teaching Materials**

A movement similar to a mobile robot can be realized using Scratch. However, the sensors that can be used are limited. It can be used as a sensor when certain events occur. The events are when the Sprite touches the specified color, when a Sprite touches another Sprite and when a Sprite approaches the specified distance for another Sprite.
Therefore, I made a Scratch application. The display image is shown in Figure 3. A child insect travels from left to right on the road surrounded by blue and red lines. I let elementary school students program the child insect to reach the parent insect. First, the children receive an explanation of the program when the road is straight. In that case, the program is completed by repeating the forward block. Next, children tackle the problem of scenes with curved roads. In that scene, the program needs to add a conditional statement that a child insect turns when it touches a blue or red line. Next, children tackle the problem of scenes that a frog appears in the center of the road. The frog eats the child insect, so the child insect must avoid getting close to the frog. In that scene, the program needs to add a conditional statement that a child insect turns when it approaches the specified distance for a frog. In Figure 3, Green button straightens the road. The orange button turns the road into a curve. Purple button puts two frogs on the road. If the user clicks on a frog, the frog moves off the road.
**Classroom Practices**

In June 2019, I practiced Scratch programming lessons for sixth graders in Kurima Elementary School. First, I gave a correct program when the road is straight. Next, I taught how to write conditional statements. After I taught how to bend when a child insect touches the red line, I let the children create a program of bending when a child insect touches the blue line. Next, I taught how to avoid when a child insect approaches the specified distance for a frog, I let the children create a program of avoiding two frogs. The two frogs scene is shown in Figure 4.

With Scratch alone, children can program similar movements as when using a mobile robot. However, there is a difference in using a mobile robot. Scratch cannot assume physical troubles that occur during the operation of a mobile robot. Scratch Sprite works logically. Mobile robots are likely to move in trouble in the real world. Mobile robot slides on wheels when travel distance is less than planned. In STEM education, it is important to deal with real-world troubles. However, I think that ideal programming is enough for the beginning of STEM education. I think it will be useful for Scratch alone.

There is a problem when moving with Scratch. Judgment is made in the entire Sprite area to touch the specified color. Therefore, it happens that Sprite cannot get out of touching the specified color. The scene is shown in Figure 5. Depending on the parameters of the program that touches blue and then goes down and rotates to the right, it causes a movement to continue drawing a circle. Sprite draws a circle while backing behind. When using a mobile robot, this phenomenon does not occur because the sensor position is one point. Sprite’s touch sensor is a whole aspect of Sprite, so it takes a technique to get out of sensing.

![Figure 5. An example of trouble scene](image)

The above troubles are likely to occur if the position of the frog is changed freely. Therefore in classroom practice, the position of the frog was not changed freely.

**STEM EDUCATION USING DRONES**

**A Combination of Drone and Scratch**

In recent years, children have become very interested in drones. People are more likely to get drones and see them more often. Therefore, using drones for STEM education can make children more attractive. I think that it will become STEM education if it is programmed and controlled rather than simply flying the drone.

Ryze Tello Powered by DJI (Tello, 2019) is one of the drones that Scratch programs can control (See Figure 6). It is sold in Japanese yen at 11664 yen (USD 110). An example of Tello programming in Scratch is shown in Figure 7. An example of a block that controls Tello is shown in Figure 8. As shown in Figure 7, Tello can be controlled by the Scratch program. The "Wait ◦ secs" block in Figure 7 is absolutely necessary. If it doesn’t exist, Tello will not be able to recognize the next block command. The waiting block is needed to be ready to accept the next command.

![Figure 6. An image of tello](image)
A drone is difficult to fly manually. Training is required to control with the controller at hand. However, it is not so difficult to navigate with the Scratch program. In Figure 7, the drone takes off about 1m, moves forward 50 cm, rotates clockwise 180 degrees, moves forward 50 cm, and moves to land. This behavior is easy even for elementary school students.

The problem is that the drone is easy to drop and fragile. And there is no sensor in the drone. As shown in Figure 8, there are various movement blocks. However, because there are no blocks to detect some event, it is difficult to create conditional branch programs. A drone can attract children, but difficult to tackle difficult tasks.

Using Only Scratch

There is drone simulation software. If a program can be created with Scratch, it will show the simulation of the flying drone on the screen. (Discovery of Wheels, 2019a) is one of the simulation software that uses Scratch. The display image is shown in Figure 8. DroneSimulator2 works with the Scratch 2.0 offline editor.
DroneSimulator2 is free software developed by Rediscover of the wheel Inc., in Osaka.

If the File menu in the Scratch 2.0 offline editor while pressing the shift key is clicked, the “Import experimental HTTP extension” menu appears. Then, after selecting the “Import experimental HTTP extension” menu, it is necessary to load ScratchDrone_1.4.s2e file which can be downloaded from the DroneSimulator2 site. By using ScratchDrone_1.4.s2e file, the operation block of drone appears in Scratch. The simulation screen is displayed by executing the DroneSimulator2.exe file which can be downloaded from the same site.

This simulator can be used to draw figures in 3D space. After all, there is no block to detect events. It is difficult to create conditional branch programs. However, unlike the actual drone machine, there is no worry of hitting somewhere. Drawing figures in 3D space are very confusing. Making complex 3D movements can be difficult even for junior high school students. I think it is difficult to draw 3D donuts and coils in space.

DroneSimulator2 can control real drone (Parrot Mambo, Swing, Airborne Night/Cargo, Rolling Spider, Hydrofoil Orak) combining the Kidsdrone Android application. This information is a description of the website and I have not verified it through experiments. Parrot (2019) is sold in Japanese yen at 9201 yen (USD 86 dollars). I think it’s attractive.

The same company also offers DroneSimulator3 (Discovery of Wheels, 2019b). DroneSimulator3 works with Scratch Desktop, which is Scratch3.0 Offline Editor. DroneSimulator3 uses a Web browser. It seems that it is currently under development, but it seems to be able to control Ryze Tello.

CONSIDERATION

The good thing about LEGO is that LEGO can assemble small blocks to solve a given problem. The completed mobile robot has no assembly phase. Because there is only a programming phase, it is not enough for STEM education. In order to have the phase to assemble, the equipment will be expensive and difficult to introduce to elementary school. Expensive equipment is difficult to introduce, and it becomes group learning for 6 or 7 people. It is better to use equipment that can be used by one person. I think it’s better to teach programming to each person. I think the equipment proposed in this paper is recommended in that respect.

STEM education focuses on training creativity. Robot contests are often held in Japan. I think the robot contest is a good activity to cultivate creativity. However, robot contest activities are mostly club activities, and there are a few examples of activities in class. Therefore, only some students participate in the activities. I think it is better to use programming education to increase the creativity of more students.

There are various levels of programming using Scratch. The program described above, where insects escape
from frogs, was suitable for sixth graders. I think the program that uses ProtchEditor is suitable for fifth graders. Also, I think that the program that uses DroneSimulator2 to move 3D is suitable for junior high school students. I also had various other lesson practices using Scratch (Yamamori, 2019). For first graders, I had children draw a picture of Scratch Sprite (Yamamori & Yoshihara, 2016; Yoshihara & Yamamori, 2016). Then, after collecting the pictures, I show the moving scene of the picture. First graders can devise a drawing and know what the computer can do. I think that what children need to devise applies to STEM education.

For third graders, I was given the task of creating a program of movement from the entrance to the exit of some maze. They learned sequential and iterative processes and tried to shorten the program. For fourth graders, I was given the task of creating a program of moving around all the points like the traveling salesman problem. For the fifth-graders, I was given the task of creating a program of drawing a geometrical figure (Yoshihara & Yamamori, 2017), a beautiful figure or floor pattern. For sixth graders, I was given the task of creating a game program that answers divisors of integers. Children tried to make a program that works correctly. The key to programming thinking is to try to find the best solution among multiple correct answers. It is better for teachers to raise problems that children can consider multiple answers. The material given to STEM education is important.

CONCLUSION

LEG0 is a good teaching material but expensive. STEM education using Scratch is less expensive. When a teacher gives a task that robots progress, avoiding obstacles, using LEGO results in learning by a group of 6 or 7 people. If the teacher chooses to use a cheap mobile robot, each person can work on the task. In addition, if the teacher chooses to use only Scratch, students can work on tasks that make them think more according to the given problem.

When conducting STEM education in class, the class is only 45 minutes. Therefore, many classes are used. STEM education, with work such as assembling small blocks, will take many class lessons. From that point, it is recommended to use only Scratch.

There are cheap mobile robots controlled by Scratch. And there are cheap drones controlled by Scratch. Those materials are very attractive. In order to make each child tackle the problem, it is important to use less expensive teaching materials.

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