Practice of the Programming Education Using Arduino and the Class Support System

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Abstract: A school setting course "Introduction to Arduino" in my school is characterized by Cross-Curriculum and Problem Solving learning on information science, physics, and mathematics, and by Flip Teaching using cloud servers. The author constructed a class support system to carry out this course and was able to develop students' originality in a short time by utilizing the system.

Keywords: Physical Computing, Arduino, Programming, Flip Teaching, Cross Curriculum, Problem solving, 3G Shield (3rd Generation)

1. Introduction

The school setting course "Introduction to Arduino" is intended to bring up students' originality by creating their ingenious works (devices) using microcomputers which are designed to achieve physical computing easily, such as Arduino. This course incorporates cross-curriculum and problem-solving learning. This course also incorporates "flip teaching "and achieved the educational effect intended. Namely, teachers upload the teaching contents on cloud servers and students study them at home beforehand. At school, students conduct various activities in order to create their own works. We also constructed a class support system to conduct flip teaching, and could produce favorable results in a short time.

2. Programming education Arduino in Koishikawa

2.1 Characteristics of the programming education using Arduino

In Koishikawa, programming education using Arduino has been performed in the school setting course "Introduction to Arduino", in club activities after school, and in open laboratories.

In order to perform activities for creating original works using Arduino, it is necessary for students to have cross-curriculum problem solving ability. It is made up of programming technology (Information Science) as a core component, and of sensor technology (physics), formula manipulation (mathematics), and so on. To develop those abilities is a purpose of this course, and it allows students to experience "cross-curriculum problem solving learning".

This course has only two hours a week, and it is difficult to achieve the purpose by doing the traditional style of teaching for the whole class.
As a result, I started "flip teaching "using cloud servers.

Students watch teaching materials which a teacher uploaded on the cloud servers such as a video sharing site (YouTube) or on the online storage (OneDrive) at home as preparations for lessons. At school, the teacher can give the individual instructions to the students. In addition, students can perform activities to create their works while cooperating with each other based on the knowledge that they got from the preparations. In this way, it was available to bring up students' originality, instead of conducting knowledge transmission-centered classes.

2.2 Class recording system for programming education

In the school setting course "Introduction to Arduino", I recorded the video materials with the class recording system which I devised, and uploaded it in the video sharing site.
Students watched them as preparations for lessons at home, etc., and they conducted activities at school for solving problems and creating devices based on the knowledge that they had learned.

It is desirable to install the encoder (Microsoft Expression Encoder) in the console machine (shown in Figure 1). The author also used a capture box to connect the teacher's machine and the console machine. It connects the audio output of the teacher's machine to the audio input of the console machine. It also captures the video signals on the screen of the teacher's machine and sends them to the USB terminal of the console machine. The encoder in the console machine encodes data from the USB terminal and generates the movie file of the WMV form. If the destination to save the video file is set to the server machine, load of the console machine decreases.

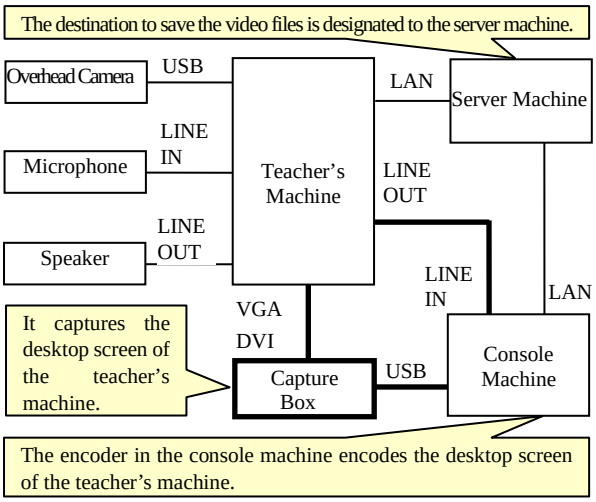


Figure 1. Class recording system
(Bold line parts are added)

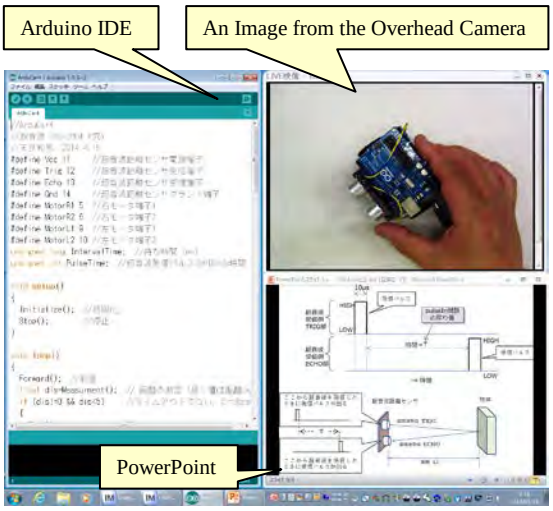


Figure 2. An example of the teaching material.
(Recording a video of the desktop screen of the teacher's machine.)

Figure 2 is an example of the desktop screen. Teaching materials to be used in the school setting subject "introduction to Arduino" are recorded on the desktop.

In the screen of Figure 2, a supersonic wave range sensor is attached to Arduino. It shows the example of structure and the program of measuring distance. In the top right corner, a picture of Arduino is displayed. A supersonic wave range sensor is attached to it using overhead camera. In the lower right corner, an explanatory figure is displayed with PowerPoint. It explains the structure about how the supersonic wave range sensor measures distance

In the left, Arduino IDE (Integrated Development Environment) is displayed. The program to measure distance is shown in it.

To use these systems makes it possible to prepare teaching materials that include a picture from overhead camera, PowerPoint, other software, and the sound from a microphone at the same time and in real time, like a DVD recorder.

The recorded videos are uploaded to the video sharing site of Google (YouTube). YouTube has a limited disclosure option without opening to the public in the world.
It is enabled by telling a URL of the uploaded videos to only authorized persons.
The author uploaded files which I recorded through the system mentioned above, and opened it only to the students who took my course.

The author also uploaded the corresponding files except the video files to an online storage OneDrive (former name SkyDrive) by Microsoft.

The students can watch videos to prepare for lessons using these files at home.
At school, based on the knowledge that they got from the preparations for lessons, they performed activities for the problem solving and the creating something that each student set as a goal.

2.3 Contents of the School Setting Course "Introduction to Arduino"

2.3.1 Annual instruction plan

This year's annual instruction plan for this course (2 hours a week) is as follows.
Particularly, the content of the learning in the first half of the first term at home is to acquire basic knowledge to handle Arduino. It will take around one year to acquire them in the form of the conventional mass teaching .However, by studying in advance at home using the cloud environment, students can finish within the period

(1)The first half of the first term (from Early April to Last May)
・At home (prior learning in the cloud environment)
Students learn about functions of Arduino, how to use it, analog and digital, digital input, digital output, analog input, analog output, binary numbers, programming (variable, substitution, input and output, sequential, divergence, repetition, function, etc.) and various sensors. (temperature, light, infrared proximity, supersonic wave, etc.)
・At School (creative activities by each student)
Students perform operation confirmation experiments on sample programs using Arduino.

(2)The latter half of the first term (from Early June to Mid-July)
・At home (prior learning in the cloud environment)
Students research various works of Arduino on the Internet based on knowledge and the experience they got in the first half of the first term. In reference to them, each student devises an original work (including the summer vacation).
・At School (creative activities by each student)
Students perform inspection experiments with Arduino and various sensors to confirm the feasibility of the works they devised.

(3)The first half of the second term (from Early September to Mid-October)
・At home (prior learning in the cloud environment)
Students think about algorithm to move their original devices on Arduino and upload document files to a cloud server.
・At School (creative activities by each student)
Students attach various sensors to Arduino and produce physical devices.
Students perform operation checks using Arduino at home referring to the document files they uploaded in which they wrote down the algorithm.

(4)The latter half of the second term (from Late October to Mid-December)
・At home (prior learning in the cloud environment)
Students make materials (documents and files for presentation) to apply for contests, and upload them to a cloud server.
・At School (creative activities by each student)
Students practice presentation in front of other students to prepare for contests using the file which they uploaded.
Students complete their works at the same time. Participation in contests (Late November)

(5)The third term (from Mid-January to Mid-March)
・At home (prior learning in the cloud environment)
Students prepare for school presentation, make articles, and upload them to a cloud server.
・At School (creative activities by each student)
Students practice presentation in front of other students using the file which they uploaded.
・School presentation and paper submission (Mid-March)

2.3.2 Examples of Cross-Curriculum Teaching Materials for " Introduction to Arduino "

The teaching materials which the author made for home learning are made up of videos and presentation files for explanation. These are uploaded on cloud servers such as YouTube or OneDrive, and are the teaching materials to develop students' cross-curriculum ability among information science, physics, and mathematics. Figure 3 is a part of them. It shows the way to treat a temperature sensor in Arduino (shown in Figure 4).

We can see that "analog and digital" and "programming " are related to the subject "information science", "temperature" and "voltage" are related to the subject "physics", "primary function" is related to "mathematics "from the teaching material above.

Thus, it is possible to develop students' cross-curriculum ability by using Arduino.

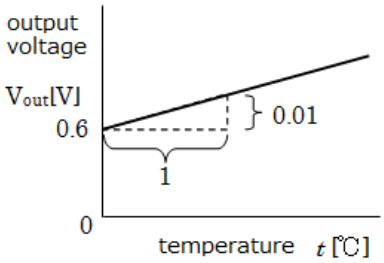
Let the analog input voltage of the AD converter stand for V, and the digital value corresponding to it stand for D, and it equals to expression(1) in the 10-bit AD converter, where D=0~1023(integer value), V=0~5

$$V = \frac{5D}{1023} \qquad (1)$$

The output voltage of the temperature sensor is 0.6[V] in the case of 0[℃]. It changes 0.01[V] with respect to the temperature change of 1 [℃]. They are shown in a graph on the lower right hand side.
The output voltage V_{out}[V]
in case of t [℃] is as follows.

$V_{out} = 0.01\ t + 0.6$ (2)

The output voltage V_{out} of the temperature sensor equals to the input voltage of the AD converter, therefore V in the expression (1) equals to V_{out} as in expression (3).



$$V_{out} = \frac{5D}{1023} \qquad (3)$$

From expression (2), expression (3),

$$t = 100V_{out} - 60 = \frac{500D}{1023} - 60 \qquad (4)$$

The program in Arduino, expression (4) is as follows.

```
int value = analogRead(A0); // analog input
//convert to temperature
float temperature = 500*(float)value/1023－60;
```

Element of Information Science (Analog and Digital)

Element of Physics (Temperature, Voltage)

Element of Mathematics (Linear Function)

Element of Information Science (Program)

Figure 3. The example of the teaching material which includes cross-curriculum contents.

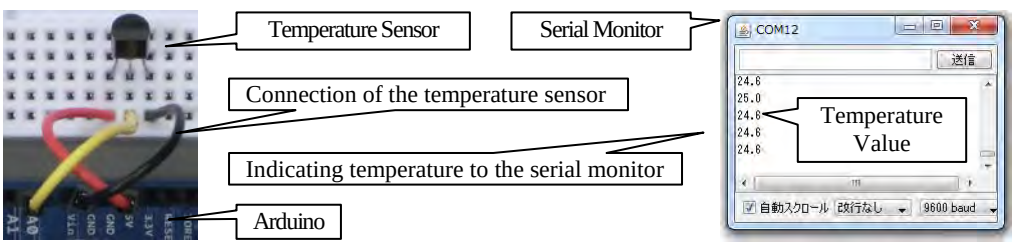


Figure 4. Connection of the temperature sensor and indicating temperature to the serial monitor

2.4 The example of a student's work

A student participated in the open laboratory (open study) last year, and the work that the student devised won the Excellence Award in a contest. (3G shield idea contest)
The summary of the student's work is as follows. This is a work which was made in combination with Arduino and 3G Shield (Figure 5 – Figure 6).3G Shield is an expansion board for the 3rd generation mobile communication network intended for cellular phones and smart phones.

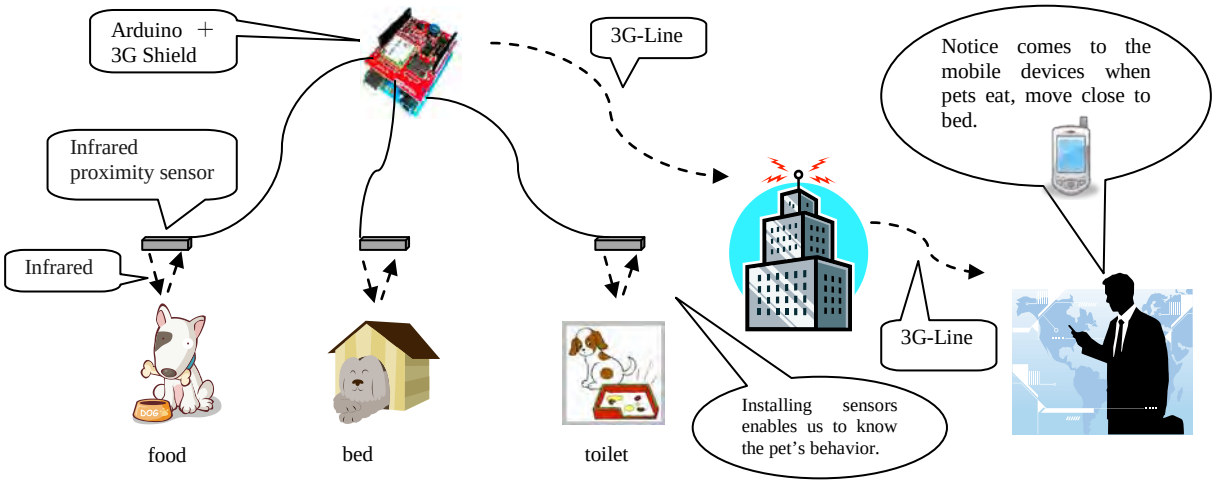


Figure 5. Schematic diagram of a pet management system (student's work)

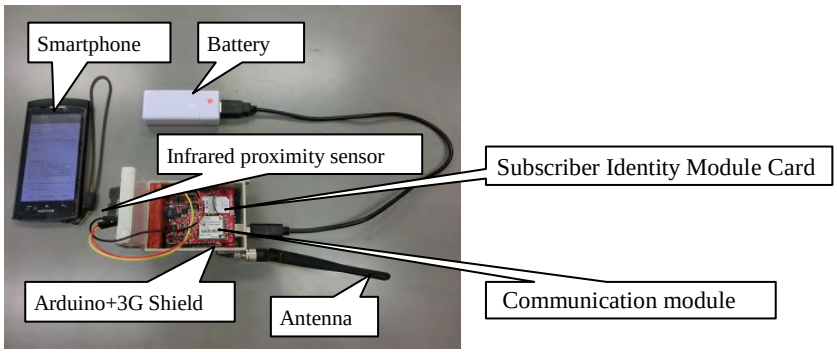


Figure 6. Pet management system (student's work)

The work title is "Pet management system". The purpose is to know the pet behaviors even if the owner of the pet is away with Arduino and a 3G shield.

Arduino is combined with 3G shield. It enables the pet owners to grasp the approximate behaviors of the pet by connecting an infrared proximity sensor and installing it on the dish, bed, restroom, etc. downward. An email will be transmitted to a cell-phone or a smartphone when the pet gets closer to an infrared proximity sensor. It can also be applied to the simplified home security as well.

3. Evaluation and Analysis

The author conducted a survey in the form of a questionnaire at school setting course "Introduction to Arduino".

Table1. Questionnaire (N=15)

	1	2	3	4	5	Mean	S.D.
Question1	0(0.0%)	0(0.0%)	4(26.7%)	5(33.3%)	6(40.0%)	4.13	0.81
Question2	0(0.0%)	1(6.7%)	4(26.7%)	7(46.7%)	3(20.0%)	3.80	0.83
Question3	0(0.0%)	2(13.3%)	3(20.0%)	6(40.0%)	4(26.7%)	3.80	0.98

Based on a 5-point Likert scale: 1＝very low, 2＝low, 3＝normal, 4＝high, 5＝very high

Question 1. Were the teaching materials uploaded in YouTube and One Drive easy to understand?
Question 2. In order to build a new system using Arduino and sensors, you had to introduce problem-solving learning, combining the knowledge of various subjects such as information, physics, and mathematics together. Were you able to understand such a technique?
Question 3. This course employs flip teaching. In flip teaching, you will watch videos at your house to prepare for the lesson, and address various tasks without listening to explanations in the lesson. Were you able to keep up with the flip teaching?

The ratio of the affirmative response to the question 1 was about 73%.
The reason for the positive responses is considered that students could learn repeatedly because the teaching materials were given by video format.

The ratio of the affirmative response to the question 2 was about 67%.
In the lesson using Arduino, students need not only the knowledge of programming, but also the problem-solving learning in which students combine the knowledge of sensor technology and formula manipulation, and so forth. Considering the responses, students were able to feel the novelty and fun in the lessons which many conventional subjects do not have. The student who made a negative response might feel a sense of incongruity in the difference from the conventional classes.

The ratio of the affirmative response to the question 3 was also about 67%. On the other hand, there were about 13% of negative responses. The standard deviation was the biggest in three questions. In order to watch videos before a lesson, decent efforts and active engagements of the students are required. Since this course was an optional, many students were already motivated and that led to the sufficient result. However, two students were not able to achieve the purpose.

4. Conclusion

(1) There are such effects by using Arduino and various kinds of shields that students can easily learn the most advanced, leading-edge technologies in a short time, and students can expand the creativity.
(2) The view may be becoming a thing of the past that each subject cultivates students' abilities and those will work as a basis when students get out into the world. The abilities which are useful in the society will be promoted better through cross-curriculum learning. The programming lessons using Arduino enables students to foster cross-curricular and problem-solving abilities effectively.
(3) The merits of the flip teaching: for the students who are eager and motivated, their academic abilities will be all the more increased because they can learn repeatedly. For the students who are not eager and motivated, they can learn repeatedly watching videos again and again, and the videos can be used as reviews, students' time for study at home will increase, and so forth.
The demerits of the flip teaching: to correspond to the students who will not prepare the lesson. However, that should not be regarded as a demerit because it is not limited to the flip teaching.

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