# The Effect of Learning Programming with Autonomous Robots for Elementary School Students

**Shuji Kurebayashi,** *eskureb@ipc.shizuoka.ac.jp*
Department of Education, Shizuoka University

**Susumu Kanemune,** *kanemune@acm.org*
Computer Center, Hitotsubashi University

**Toshiyuki Kamada,** *tkamada@auecc.aichi-edu.ac.jp*
Department of Technology Education, Aichi University of Education

**Yasushi Kuno,** *kuno@gssm.otsuka.tsukuba.ac.jp*
Graduate School of System Management, University of Tsukuba

## Abstract

It is possible to evaluate the effect of learning programming and controlling objectively by examinations. However, investigation the amount of knowledge on programming and controlling seems not to be enough because it only shows how much of knowledge is established to learners. Thus, this approach does not unveil what kinds of abilities are gained in students through learning computer programming.

We first try to find out the method of evaluation other than the objective test in order to answer the above question. As a result, we finally set to study the effect of learning programming from the viewpoint of "Technology Literacy" instead of conventional issue of creative thinking or logical thinking.

Recently, numbers of incidents and accidents relating to computer technologies are occurred and we mundanely receive news reports on that. People those who have technology literacy can understand the background of the report, but people those who are lack in technology literacy do not understand it and they cannot explain why the incident or accident is occurred.

Then, we set up a hypothesis that there is a difference of understanding the outline of incidents or accidents between students those who have learned the computer programming and students those who have not learned it. We think if there were a difference, we would be able to conclude that the learning computer programming has a good effect for students on developing technology literacy itself.

To bear out our hypothesis, we made a survey on the difference of the knowledge contributing to understand the reason of an accident between two groups of elementary school students with the same age; one is a group those who are learned computer programming by controlling robotic cars and the other is a group those who are not learned computer programming at all. The intended accident was the fatal accident by an elevator manufactured by Schindler Elevator Company occurred in Tokyo, 2006. As a result, we could see the difference between them.

In this paper, the programming language "Dolittle" which is a teaching material for programming lessons and the target robotic car which is controlled by Dolittle are introduced. Then the content of programming lessons conducted in an elementary school and questionnaires to the students are explained. The survey result and the analysis of it are also reported.

## Keywords

Learning Programming, Autonomous Robot, Educational Evaluation, Technology Literacy

# Introduction

The educational value of learning programming is described in various practices (Saeki, 1986). However in Japan, the range of dealing with the programming is limited as written in the course of study by the government (Ministry of Education, Culture, Sports, Science and Technology) for junior and senior high schools; "The educator should not deeply involve the programming" (MEXT, 1998 and 1999). Thus there are a few secondary schools which take up the programming for their lessons. Similarly, in spite of the information education in elementary schools are prescribed in the "Period for Integrated Study", the example of the practice of the programming is quite limited after the revision to the current course of study (Sato *et al.*, 2005). The reason of this circumstance is that the grand design of current information education in Japan is too much emphasized fostering the "Information Application Ability" using computers (Wada, 2006). However, it is impossible for students to understand the mechanism of software and hardware only by learning the usage of application software such as word processors, spread sheets and web browsers. Moreover, it is difficult to understand or have interest in accidents or incidents regarding to information technologies. Because if the person can clearly conceive the overview of the accident by hearing the terms like "error in the program" or "system down" in news reports which are included in the description of the cause of accidents is depend on the knowledge of not only the usage of computers but also the mechanism of computers.

Therefore, we have made a survey on the knowledge regarding to the understanding of the cause of the fatal accident by an elevator developed by Schindler Elevator Company occurred in Tokyo on June 3, 2006 (Japan Times, 2006; Wikipedia) by showing the report of a newspaper to two groups of elementary school students; one has a experience of learning programming and controlling, the other does not have them at all. As a result, we find the difference of students' understanding of the accident between these two groups.

In this paper, firstly the programming language "Dolittle" (Kanemune, *et al.*, 2004 and 2005) which is a teaching material for lessons and the target robotic car which is controlled by Dolittle are introduced. Secondary, the content of programming lessons conducted in an elementary school is explained. Thirdly, the material distributed to students and the content of the questionnaire are presented. Lastly the result of our survey and the analysis of it are reported.

# Lessons

We asked a teacher in Osu Elementary School in Fujieda city, Shizuoka prefecture to conduct lessons on programming and controlling robotic cars in the "Period for Integrated Study" subject. The teacher gave lessons in two classes of 6$^{th}$ grade (11 years old). The total number of the students is 64. The lessons are held from June to July in 2006. Each period is 45 minutes. The curriculum of the lessons is shown in Table 1.

*Table 1. The curriculum of the lessons*

| | The theme of the lesson | Periods |
|---|---|---|
| **1** | How to start up "Dolittle" | 2 |
| **2** | Move the turtle in Dolittle | 2 |
| **3** | Change the looks of the turtle and drawing simple figure | 2 |
| **4** | Let's move the turtle and figures with timer | 2 |
| **5** | Let's move the robot | 2 |
| **6** | Let's challenge the maze (1) | 2 |
| **7** | Let's challenge the maze (2), Summary | 2 |

Lessons are held in the computer room. Because of the number of installed PCs in the computer room is 20, pairs of students shared each PC. The specification of PCs is as follows:

- CPU: Celeron 400MHz
- Memory: 64MB
- Operating System: Windows 98

## Graphics Drawing Program Using Dolittle

Dolittle is an object-oriented programming language designed for school education. It has simple language syntax and the programmer can use their local language such as Japanese, Korean and English for instructions and identifiers including variable names. Then Japanese students can program using Japanese keywords. In Japan, English classes are not held in elementary schools, then students in Japanese elementary school use Japanese in programming Dolittle.

Figure 1 shows the sample program of animated graphics in Dolittle. Students wrote this kind of program and enjoyed creating their own animated graphics.

```
Kameta=turtle ! create.
[Kameta ! 100 forward 120 rightturn] ! 3 repeat.
Triangle=Kameta ! makefigure (red) paint.
Clock=timer ! create 1 period 10 duration.
Clock ! [Triangle ! 36 rightturn] execute.
```

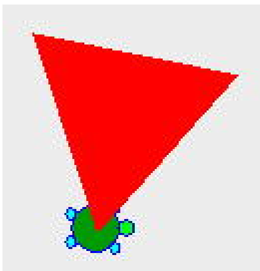

*Figure 1. A sample program of Dolittle and the screen shot of this program*

The first line of the program creates a turtle object named “Kameta”. The second line draws a triangle with turtle graphics. The third line changes drawn graphic into figure object named “Triangle” and paint it with red color. The fourth line creates timer object named “Clock” and set up some properties of it. The fifth (last) line realizes an animation by asking timer object for rotating “Triangle” object.

## Controlling Program for Robotic Cars

The robotic car mounts biaxial robot controller board which we have developed (Kurebayashi *et al.*, 2006). The controller board has embedded microcontroller with our original firmware. Thanks to this firmware, users of this robot can write a program with up to 39 steps into the microcontroller. The program is transferred from PC to the controller board with an embedded infra-red lay device. Figure 2 shows the robotic car which is used in our experimental lessons.

Table 2 shows robot controlling instructions for Dolittle. Figure 3 shows an example controlling program written in Dolittle. In this program, a serialport object (which is used to communicate between the PC and the robot via serial port) named “Robo” is created first, then a method named “transfer” is defined to “Robo” object and several robot control instructions are written in it.

This method is invoked after the serial port is opened. With the written control instructions, the robot executes following motion:

- Start executing the program when the sensor switch is pressed
- Go forward until the front sensor is pressed by touching to the front wall
- Go backward and turn to the left
- Go forward until the front sensor is pressed by touching to the front wall
- Go backward and turn to the right

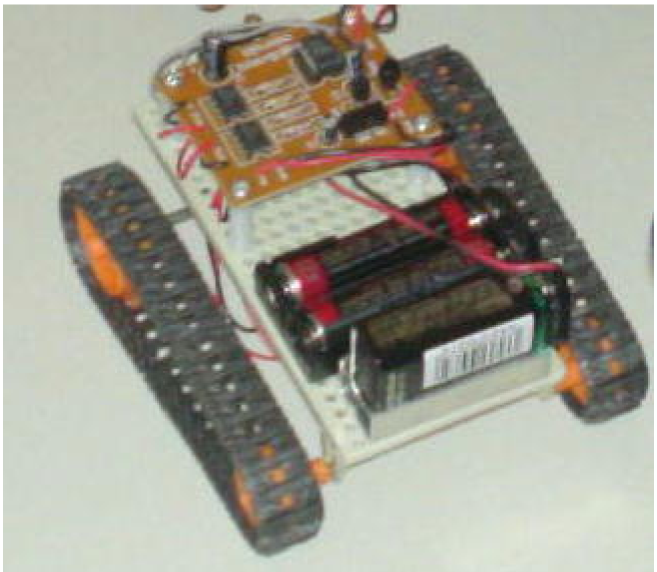

*Figure 2. The robotic car used in our experimental lessons*

*Table 2. Robot control instructions*

| **Instruction** | Explanation | Example |
|---|---|---|
| opensesame | Open the serial port | “com1” opensesame |
| closesesame | Close the serial port | |
| leftforward | Turn the left wheel forward | 10 leftforward |
| rightforward | Turn the right wheel forward | 10 rightforward |
| forward | Turn both wheels forward | 10 forward |
| leftback | Turn the left wheel backward | 10 leftback |
| rightback | Turn the right wheel backward | 10 rightback |
| back | Turn both wheels backward | 10 back |
| startrobot | Start of the robot controlling | |
| endrobot | End of the robot controlling | |
| forwarduntilcollision | Go forward until the sensor switch is pressed | |
| switchstart | Execute instructions when the sensor switch is pressed | |

*The unit of the argument of instructions which turn a wheel is 0.1 second.

```
Robo=serialport ! create.
Robo:transfer=[!
   startrobot
   switchstart
   forwarduntilcollision
   10 forward 15 rightforward 15 leftback
   forwarduntilcollision
   10 back 15 leftforward 15 rightback
   endrobot].
Robo ! “com1” opensesame.
Robo ! transfer.
Robo ! closesesame.
```

*Figure 3. A sample robot controlling program with Dolittle*

*Figure 4. Students controlling their robotic cars with their programs*

We have built simple maze made with wooden panels and offer it to the lesson. Students input a program in Figure 3 and try to modify or arrange it in order to go through the maze. Figure 4 shows the scene of students controlling their robots.

# Questionnaire

## Document Distributed to Students

Before questionnaire, we have provided a document to students as background information for them. The content of the document is regarding to the fatal accident of an elevator developed by Schindler Elevator Company occurred in Tokyo on June 3, 2006. The reason why we adopt this accident is that the fundamental cause is a flaw in controlling program of the elevator and this is related to computer programming and control. Furthermore, we hope the situation of the accident could be recognized even by elementary school students because elevators are familiar machines and everyone seems to have experiences of using them.

The document is basically based on the explanatory article from Asahi Shimbun newspaper Internet edition (Asahi Shimbun, 2006) and the explanatory pictures from Japan Elevator Association website (JEA, 2006). The document is composed of two pages. In the first page, we have placed articles which explain the outline of the accident. In the second page, we have placed an article explains the cause of the accident and supplementary pictures explaining the architecture of elevators.

## Content of Questionnaire

We have made students to read the document before answering questions. The number of questions is six. The format of the answer to question from number 1 to 4 was five level scales (5: strongly agree, 4: agree, 3: not sure, 2: disagree, 1: strongly disagree) and number 5 and 6 was description. Question number 5 and 6 are for examining the extent of understanding the content of question number 3 and 4.

The actual questions to students are as follows:

**Question 1:** Did you know this accident of the elevator?

**Question 2:** Can you understand the architecture of elevators?

**Question 3:** Can you understand what is wrong by reading the sentence that the cause of the accident is “flaw in controlling program (errors in controlling program)”?

**Question 4:** Can you explain the cause of the accident to other people?

**Question 5:** What is controlled by the control board? Answer by looking at the picture in the document.

**Question 6:** Please write your opinion of what kind of matters do you want to be taken care by the people in the elevator company in order to prevent the accident like this anymore.

## Procedure of Sending Out the Questionnaire

On sending out the questionnaire, we have explained the following notices to the teacher. The time to answer questions had set to 20 minutes. Because there are some difficult words and statements for elementary school students in the document, the teacher had to give supplemental description to the students. However, we asked for the teacher not to explain the architecture of elevators and the role of controlling programs.

**Notice 1:** Please read out the document.

**Notice 2:** It is allowed to teach how the questioned Kanji (Japanese letter) to read.

**Notice 3:** Never answer to the question regarding to the architecture of elevators and the role of controlling programs.

## Control Group

As a control group, we have chosen 6th grade (11 years old) students in Fujieda Chuo Elementary School in Fujieda city, Shizuoka prefecture. The number of students is 29. The students’ experiences of operating computers are limited to using application software such as a web browser, word processor and paint software. There are no students who have an experience of a programming or controlling robots.

# Result

The summary of two groups of students; (1) 64 elementary school students (6th grade, 11 years old) who have experienced computer programming and controlling robotic cars with computer in October, 2006; (2) 29 students with the same age, not experienced computer programming or controlling is shown in from Table 3 to Table 6. In these tables, answer number 5 and 4 are positive answers, and answer number 1 and 2 are negative answers.

*Table 3. Question 1: Did you know this accident of the elevator? (%)*

| | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|
| **Experienced** | 29.7 | 50.0 | 6.3 | 6.3 | 7.7 |
| **Not Experienced** | 24.1 | 44.8 | 17.2 | 3.4 | 10.5 |

*Table 4. Question 2: Can you understand the architecture of the elevator? (%)*

| | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|
| **Experienced** | 4.7 | 23.5 | 40.7 | 28.2 | 2.9 |
| **Not Experienced** | 3.4 | 6.9 | 58.6 | 10.3 | 20.8 |

In the summary of question 1 (see Table 3), there is no clear difference between the students who have experienced control programming (hereinafter referred to as “experienced students”) and the students who have not experienced it (hereinafter referred to as “not experienced students”). These are equivalent in the recognition of the news report. In the summary of question 2 (see Table 4), the ratio of experienced students who have positive answers (the sum of the answer number 5 and 4) is 28.2%. On the contrary, the ratio of not experienced students is 10.3%. From these results, it seems to affect the extent of understanding the architecture of the elevator for students that the presence or absence of experience of the control programming.

*Table 5. Question 3: Do you understand what is wrong? (%)*

| | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|
| **Experienced** | 11.0 | 39.1 | 32.8 | 14.1 | 3.0 |
| **Not Experienced** | 0.0 | 0.0 | 44.8 | 20.7 | 34.5 |

*Table 6. Question 4: Can you explain the cause of the accident to other people? (%)*

| | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|
| **Experienced** | 4.7 | 25.0 | 32.9 | 29.7 | 7.7 |
| **Not Experienced** | 0.0 | 3.4 | 27.6 | 37.9 | 31.1 |

In the summary of question 3 (see Table 5), the ratio of experienced students who have positive answers is 50.1% and the ratio of not experienced students is 0%. In the summary of question 4 (see Table 6), the ratio of experienced students who have positive answers is 29.7% and the ratio of not experienced students is 3.4%. From these results, it seems to be inferable that the experience of control programming affects the understanding of the cause of the accident.

Figure 5 and 6 are graphs of the ratio by classifying contents of answers to question 5 and 6 respectively. Answers to the question 5 are classified into 4 categories; “moving machinery such as winch and doors”, “counter weight”, “other elements (including unclear statement)” and “not sure”. From this summary, the ratio of experienced students answering “moving machinery” was

37.6% and the ratio of not experienced students was 13.6%. Furthermore, the ratio of experienced students answering “not sure” was 35.9% and the ratio of not experienced students was 62.1%. Besides, the ratio answering “counter weight” which is not related to controlling is small in experienced students meanwhile it is more in not experienced students. As for question 6, answers to it are classified into 3 categories; “point out the inspection point (such as a control board or programs)”, “not point out” as represented by the description of “People of the elevator company should inspect steadily”, and “unclear”. From this summary, we could see two large differences between experienced students and not experienced students; the ratio of the answer “unclear” is 0% in experienced students and 27.6% in not experienced students. The ratio of pointing out the concrete inspection point is 20.6% in experienced students and 0% in not experienced students. From above results, it is clear that there is a difference in the capacity of understanding the cause of the elevator accident. Consequently, we can conclude that the experience of controlling program affects the ability to figure out the concrete cause of the accident and the perspective on the way of inspection.

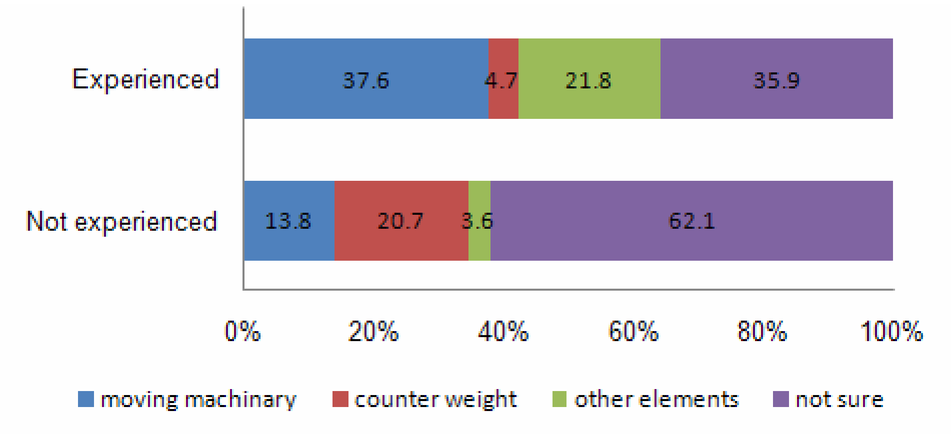


*Figure 5. Summary of the answer to the question 5: What is controlled by the control board?*

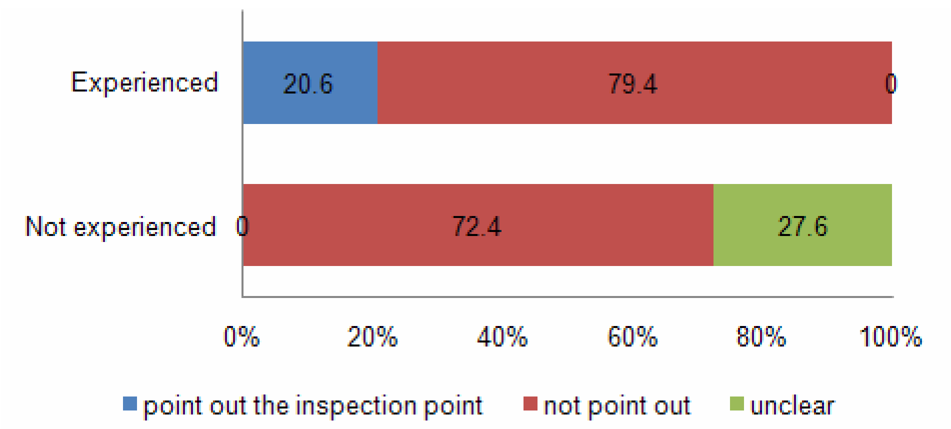


*Figure 6. Summary of the answer to the question 6: What should be done to prevent accidents like this?*

## Discussion

The ratio of the students with positive answers to question 3 and 4 is more in experienced students than not experienced students. The reason of this seems to be that the experienced students can easily imagine which components are controlled by the computer program. Indeed, 37.6% of experienced students answer moving machineries to question 5 as a target of control board. Experienced students should have a concrete image of controlling mechanism through the robot programming such as controlling motor rotations and selecting proper behaviour according to sensor inputs. Then they should have an ability to imagine the motion of each component of elevators. Furthermore, the ratio of not experienced students who can point out concrete inspection point is zero. This would strongly support above thought.

## Concluding Remarks

We have investigated the difference of the extent of understanding the elevator accident between the existence and nonexistence of the experience of learning controlling programming. The 6th grade (11 years old) students have shown the clear difference.

Sometimes teachers try to make their students to engage in research work in order to induce interest in some accidents or incidents in the world. However, the success or failure of the class is not only willingness of students but also an education that can understand the cause or the background of the incident from documents they have obtained. For this reason, educators of information education should approach from the view point of "Technology Literacy" which is an ability of "hearing from a specialist about technology, and understanding, using, assessing and managing it". Then, learning computer programming have to contribute to make people living in highly computerized world understand the substantial risk of accidents or incidents.

We would like to thank the teachers and the students of Osu Elementary School and Fujieda Chuo Elementary School for the contribution to the conduction of lessons and the answer to the questionnaires.

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