Computational Thinking Education Using Stickers and Scanners in Elementary School Classes

Akiyuki Minamide
International College of Technology, Kanazawa, Kanazawa-shi, Ishikawa, Japan
minamide@neptune.kanazawa-it.ac.jp

Kazuya Takemata
International College of Technology, Kanazawa, Kanazawa-shi, Ishikawa, Japan

Hirofumi Yamada
Kanazawa Institute of Technology, Hakusan-shi, Ishikawa, Japan

Abstract

Programming education will be compulsory at elementary schools from fiscal 2020 in Japan. Programming education in elementary school does not teach programming language coding, but computational thinking. This paper describes a new programming education method using stickers and a scanner that combine the features of unplugged programming and physical programming. The new materials developed in this study offer superior features compared to commercial materials, such as low cost, use in lower grades class in elementary school, and no need for teacher ICT skills. Demonstration experiments were conducted on 66 third-grade elementary school students to confirm the effectiveness of the materials. The children used the new teaching materials without being confused, and the teachers were able to smoothly teach. From this result, it was confirmed that this teaching material could be used in the lower grades class of elementary school.

2012 ACM Subject Classification Social and professional topics → Computer science education

Keywords and phrases computational thinking, programming education, programming with stickers

Digital Object Identifier 10.4230/OASIcs.ICPEC.2020.16

1 Introduction

In Japan, programming education will be compulsory at elementary schools starting in fiscal 2020. Programming education in elementary schools does not teach programming languages as higher education institutions do but teaches computational thinking [7, 8]. However, there are some problems with introducing programming education in elementary school.

Japanese elementary schools have 30 to 35 children per class, and one teacher must be in charge of one class. Although programming materials used by a small number of children are commercially available, there is no teaching material intended for large classes. In addition, elementary schools do not have sufficient budget for facilities such as ICT (Information and Communication Technology) devices and robots including personal computers, and elementary school teacher does not have programming skill and knowledge to teach children. In order to solve these problems, it is necessary to consider programming education throughout the school and society, and new teaching materials that require less capital investment and have nothing to do with the programming skills of teachers are needed.

In this paper, we describe a new programming education method using stickers and a scanner to solve these problems.

First International Computer Programming Education Conference (ICPEC 2020).
Editors: Ricardo Queirós, Filipe Portela, Mário Pinto, and Alberto Simões; Article No. 16; pp. 16:1–16:7

OpenAccess Series in Informatics
Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany

2 New Programming Education Method

2.1 Comparison of programming education types

Programming education is divided into three areas: unplugged programming [2, 1], visual programming [3, 5], and physical programming [6, 4]. Table 1 summarizes the features of each facet of programming education when teachers conduct classes at an elementary school.

Table 1 Comparison of programming education types.

	Used items	Initial installation	Tech. knowledge required costs	Children's interest by teachers	Ease of class management
Unplugged Programming	Cards Papers	**5** Low cost	**5** Not required	**2** Lose interest easily	**5** Possible with one teacher Possible in any classroom
Visual Programming	PCs or Tablets	**3**	**3** A little required	**4** Interested	**3**
Physical Programming	PCs or Tablets Sensors, Robots	**2** High cost	**2** Strongly required	**5** Very interested	**2** Difficult to prepare

(5: Excellent; 4: Good; 3: Fair; 2: Poor; 1: NA)

It is commonly thought that programming needs to be learned on a computer, but if students are to gain a deeper understanding of the concept of the program rather than operating the program blindly, learning in the unplugged form is effective. Furthermore, unplugged programming has positive features, including low budget requirements and ease of use in the classroom. Since programming classes in lower grades are conducted in a general classroom rather than in a laboratory, there is almost no space for equipment, and it is difficult to perform visual programming and physical programming. On the other hand, unplugged programming can be handled relatively easily in a small space.

However, there is a problem that children get bored faster than with physical programming methods that use robots. Children seem to be impressed and highly motivated by physically controlling robots. Therefore, in this study, we propose a new educational method that makes use of the features of both unplugged and physical programming.

2.2 New programming education method

Figure 1 is an outline of the new programming education method. A new teaching method uses stickers and a scanner with instructions for controlling a robot car (PS: programming sticker). Each child thinks of a procedure for solving problems at his/her desk and applies a sticker to control the robot according to the procedure.

Children use the new materials in the following steps.

1. The children will be given the task written on the task sheet. For example, give the children the task of controlling a robot car in a supermarket to buy rice and curry food.
2. Children choose the ingredients to buy and think of a route to buy them efficiently. The PS is a special sticker that can be stuck or peeled off any number of times, and can be programmed by the child in trial and error.
3. Next, when the programming sheet with PS stuck is read by the overhead scanner (Fujitsu ScanSnap SV600), it is automatically coded and the control instruction is transferred to the robot car via the computer.
4. The children can check the operation of the program by running the robot car (LEGO EV3) containing the program created by themselves on the actual course.

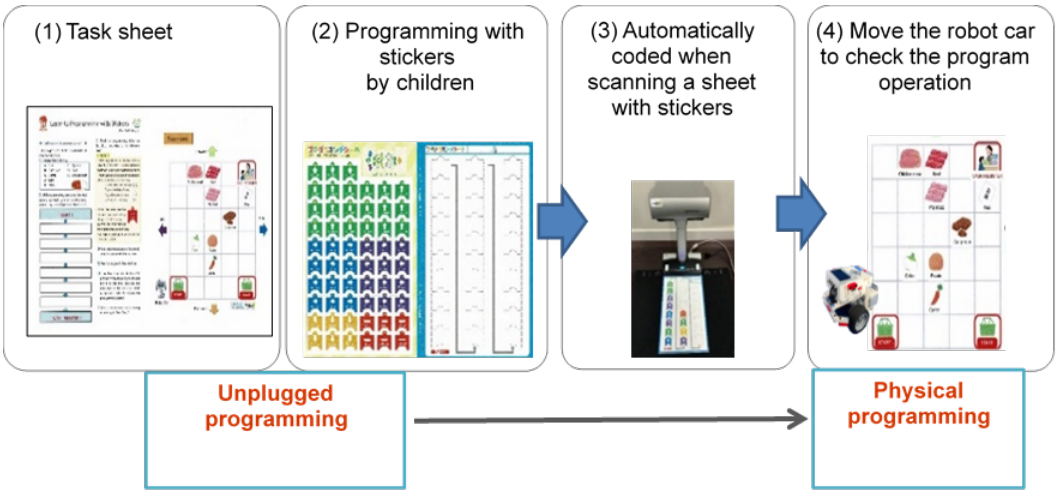

Figure 1 Outline a new programming education method using programming with stickers (PSs) and a scanner.

The operation is simple from scanning to moving the robot car, and it can be performed only by children without the help of teachers. Therefore, an elementary school teacher can give lessons in the form of 1 (teacher) vs. N (the number of children). Furthermore, unplugged programming is performed in the program creation process, and the operation check of the created program is physical programming. This has the advantage of reducing the number of devices required for the class, such as robots and personal computers.

2.3 Educational system configuration

Figure 2 shows the configuration of the educational system. A non-contact scanner (Fujitsu ScanSnap SV600[1]) was used to scan an image of the programming sticker. This scanner is suitable for scanning uneven sheets, such as programming stickers, as it does not touch the stickers during overhead scanning. A laptop computer captures the image from the scanner, identifies the JPEG image of stickers, and converts it into robot control information (JavaScript Object Notation data: JSON data). Since this image recognition is performed by the color of the sticker, even if the sticker put by the children is inclined, it can be recognized reliably. The LEGO Mindstorms EV3 was used for the robot car. LeJOS firmware[2] was installed on EV3 to realize JAVA programming with LEGO. The JSON data were sent from the computer to EV3 via a USB cable. There was no need for any expert knowledge, as all steps just require the pressing of a button.

2.4 Programming Sticker and Programming Sheet

Figure 3 shows programming stickers for lower grade elementary school children. The left side is programming stickers and the right side is a sheet to put stickers on. The PSs and the sheet are all made of paper, and the sheet surface is treated to make it easy to remove the sticker.

[1] https://www.fujitsu.com/global/products/computing/peripheral/scanners/scansnap/sv600/
[2] https://sourceforge.net/projects/lejos/

The stickers can be put on and peel off, so children can programming with stickers by trial and error. Since the children are new to programming, only five stickers were used: Straight, Right turn, Left turn, Reverse and Stop.

Figure 2 Configuration of the educational system.

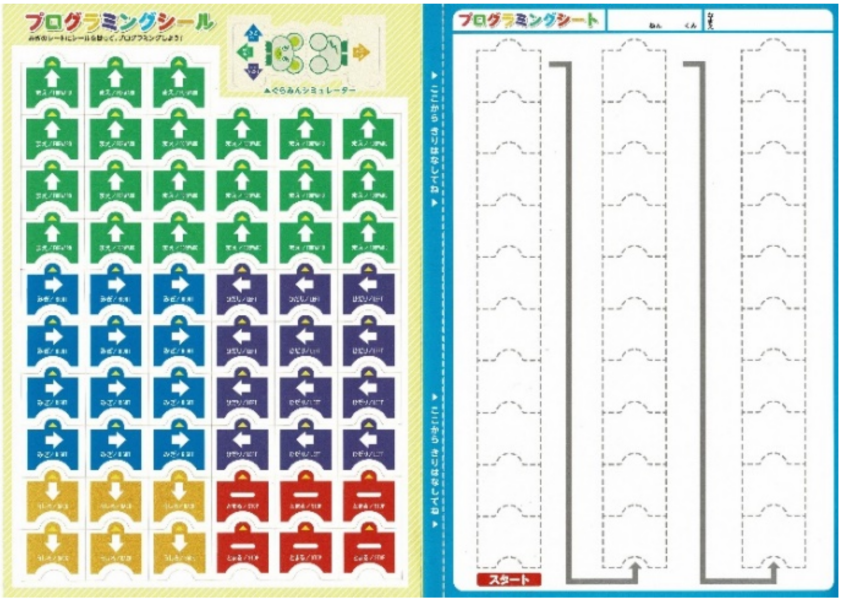

Figure 3 Programming stickers (left side) and a programming sheet (right side).

3 Trial Experiment of New Programming Education

3.1 Trial experiment in elementary school classes

Trial experiments were conducted in an elementary school using new teaching methods. The target children were 66 third-grade of Meiko Elementary School, Hakusan City, divided into two classes.

Figure 4 shows the task sheet prepared for this class. The actual task sheet used was written in Japanese. The children were tasked with buying food for rice and curry by controlling a robot in a supermarket.

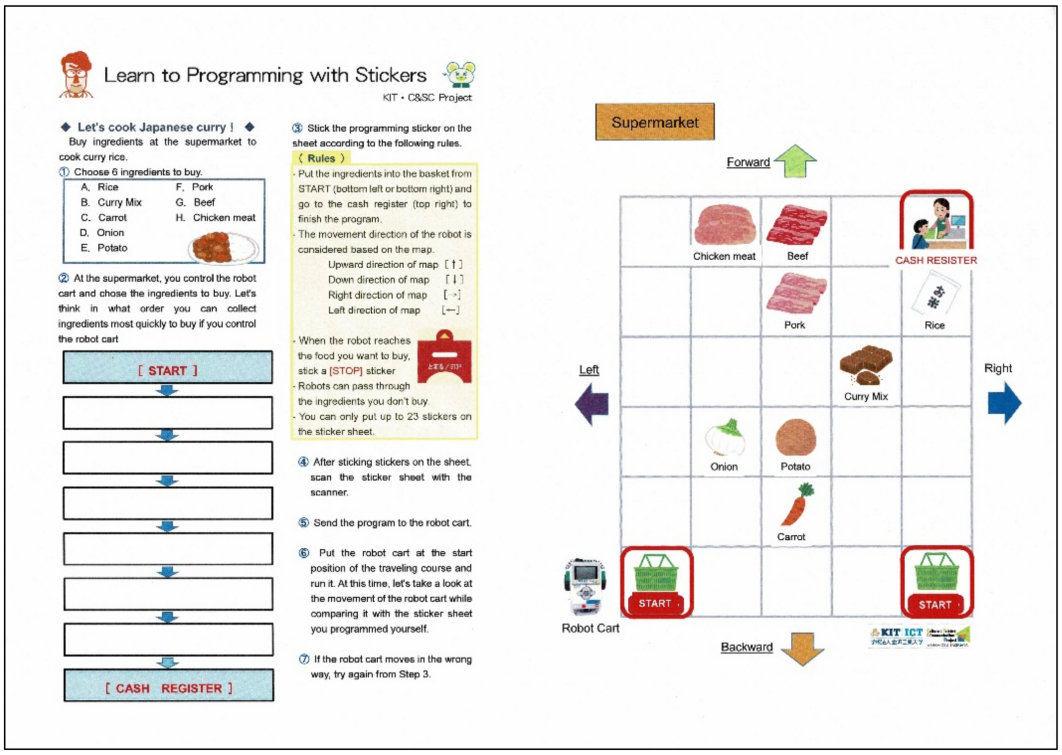

Figure 4 Task sheet, "Buy Japanese curry ingredients in a supermarket".

The task sheet and programming sticker were distributed to each student. Two sets of scanners and laptop computers, eight robots, and eight traveling courses of robots were prepared.

Figure 5a shows a picture of a child programming using PSs. Many children were able to stick PSs on the sheet freely without any assistance from teachers. Figure 6 shows a scan of the programming sheet and data transfer to the robot car. It takes only about 15 seconds from the scanning of the programming sheet to the completion of the data transfer, greatly reducing equipment usage time. Therefore, eight robot cars were enough to deal with 33 children. Figure 5b shows the robot car moving on the traveling course. By comparing the movement of the robot car with the programming sticker, the child can confirm the operation of the program he or she thought. If the child notices a mistake in the movement of the robot, the child will notice it and can re-stick the sticker.

3.2 Questionnaire after class

A questionnaire survey was conducted to confirm that the proposed teaching materials could be used. The children were 35 boys and 31 girls, and 86% of them experienced programming classes for the first time. Figure 7 shows the results for the following questions.

Q1 Was the content of this class difficult for you?
Q2 Is the programming sticker easy to use?
Q3 Is the scanner easy to use?

(a) Programming using PSs.

(b) Program operation check.

Figure 5 Images from students.

Figure 6 Scanning PSs stuck on the sheet and transferring data to the robot car.

Q4 Is the robot car easy to use?
Q5 Did you enjoy this class?
Q6 Were you interested in programming after this class?
Q7 Do you want to take programming classes again?

From the results of Q2, Q3, and Q4 questionnaires, it became clear that the teaching material system components can be used by children without problems. Additionally, more than 90% answered that they enjoyed this class, and more than 85% answered that they were interested in programming. The survey results suggest that the new teaching methods we have developed can be used for programming education for elementary school children.

4 Conclusions

A new programming educational method using stickers and scanner was described. This method combines the features of unplugged programming and physical programming, and the new teaching materials developed have excellent features compared to commercially available teaching materials, such as lower cost, use in lower grades of elementary school, and no need for ICT skills for teachers. Trial experiments were conducted on 66 third-grade elementary school students to confirm the effectiveness of the materials. It became clear that the new educational method we developed could be used for programming education for elementary school children, as evidenced by the results of the questionnaire.

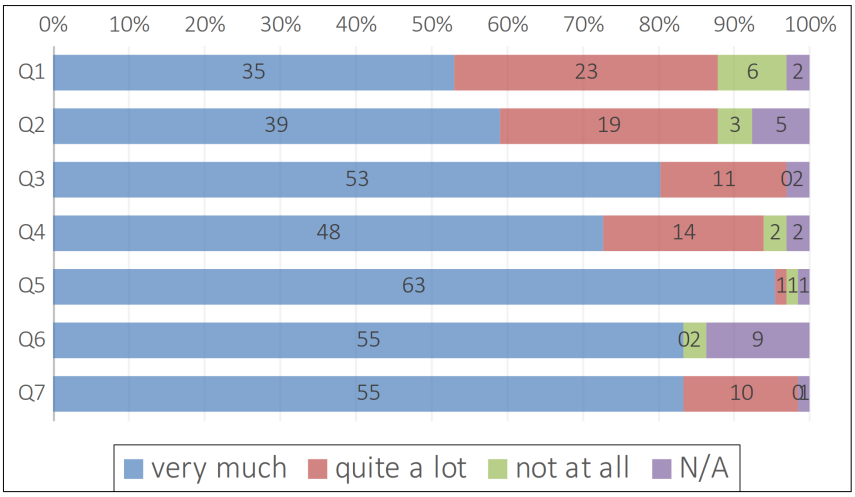

Figure 7 Results of the survey.

References

1 Christian P. Brackmann, Marcos Román-González, Gregorio Robles, Jesús Moreno-León, Ana Casali, and Dante Barone. Development of computational thinking skills through unplugged activities in primary school. In *Proceedings of the 12th Workshop on Primary and Secondary Computing Education*, WiPSCE '17, page 65–72, New York, NY, USA, 2017. Association for Computing Machinery. doi:10.1145/3137065.3137069.

2 Yvon Feaster, Luke Segars, Sally K. Wahba, and Jason O. Hallstrom. Teaching cs unplugged in the high school (with limited success). In *Proceedings of the 16th Annual Joint Conference on Innovation and Technology in Computer Science Education*, ITiCSE '11, page 248–252, New York, NY, USA, 2011. Association for Computing Machinery. doi:10.1145/1999747.1999817.

3 Takayuki Dan Kimura, Juli W Choi, and Jane M Mack. Show and tell: A visual programming language. *Visual Programming Environments: Paradigms and Systems*, pages 397–404, 1990.

4 Pamela B. Lawhead, Michaele E. Duncan, Constance G. Bland, Michael Goldweber, Madeleine Schep, David J. Barnes, and Ralph G. Hollingsworth. A road map for teaching introductory programming using lego© mindstorms robots. In *Working Group Reports from ITiCSE on Innovation and Technology in Computer Science Education*, ITiCSE-WGR '02, page 191–201, New York, NY, USA, 2002. Association for Computing Machinery. doi:10.1145/960568.783002.

5 Orni Meerbaum-Salant, Michal Armoni, and Mordechai (Moti) Ben-Ari. Learning computer science concepts with scratch. In *Proceedings of the Sixth International Workshop on Computing Education Research*, ICER '10, page 69–76, New York, NY, USA, 2010. Association for Computing Machinery. doi:10.1145/1839594.1839607.

6 Achille Messac. Physical programming - Effective optimization for computational design. *AIAA Journal*, 34(1):149–158, January 1996. doi:10.2514/3.13035.

7 Jeannette M. Wing. Computational thinking. *Communications of ACM*, 49(3):33–35, March 2006. doi:10.1145/1118178.1118215.

8 Jeannette M. Wing. Computational thinking and thinking about computing. In *2008 IEEE International Symposium on Parallel and Distributed Processing*, pages 1–1, 2008.