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Motivation Effects of Using Actual Robots Controlled by the Scratch Programming Language in Introductory Programming Courses*

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This paper reports on the effects of a teaching tool that controls actual robots during introductory education in computer programming among high school students. The effects of the tool were investigated by means of a questionnaire following two types of experience based programming classes, namely one class that used actual robots and one that did not. Questionnaire surveys were completed before and after the classes in order to determine whether or not the participants' level of interest in information and communication technology had changed. Statistical analysis of the questionnaire results showed that the use of actual robots is an effective way to raise students' level of interest in information and communication technology. It was found to be particularly effective among participants who liked subjects other than science and those who had a lower level of understanding information sciences that they were taught in high school.

Keywords: programing education; scratch; actual robot

1. Introduction

The last two decades have seen the rapid development of an information-based society, supported by information and communication technology (ICT). Along with this development, user interfaces have also changed dramatically from character based user interfaces (CUIs) to graphical user interfaces (GUIs). Although excellent user interfaces allow most people to use ICT equipment intuitively, such equipment remains just like a black box for many people. Indeed, it seems to be difficult for beginners to use a CUI in learning programming, despite the ever younger starting age for ICT equipment use. However, software that is an indispensable element of ICT infrastructure is usually developed by typing commands in a CUI environment. Thus, in order to allow optimal human resource development for the information based society of the future, effective programming education is one of today's prime educational challenges.

To meet this challenge, a new set of curriculum guidelines for middle and high schools (for children aged 12–14 and 15–18 years, respectively) came into force in Japan in April 2011. These new curriculum guidelines were introduced in phases so as to grow engineering talent for supporting the development of ICT infrastructure [1, 2]. Within the curriculum guideline of the subject Technology and Home Economics [3], programming education has been enhanced, with the aim of encouraging students to become ICT engineers. For instance, a course unit entitled "Measurement and Control through Computer Programs" was added to the core curriculum for middle schools. Furthermore, the curriculum guidelines for this course unit in Japanese schools require teachers to teach their students that procedures of information processing are realized by combinations of basic control structures, i.e., "Sequence," "Selection," and "Iteration" procedures. Moreover, the guidelines require students to be taught how to solve problems by using information processing procedures rather than learning the instruction words of programming language. In other words, understanding the algorithm is regarded as more important than learning the specific computer language in programming education.

Against the above socio-educational background, we developed and carried out an experience based programming class for beginner programmers [4]. In this class, participants tried to control an actual robot by means of their program, although, due to time constraints, we could not offer them the sense of accomplishment of complete programming. As limited class time prevented us from teaching them how to develop programs of control codes by C++ programming, they merely changed a few programming variables. Thus, we introduced a block based intuitive programming

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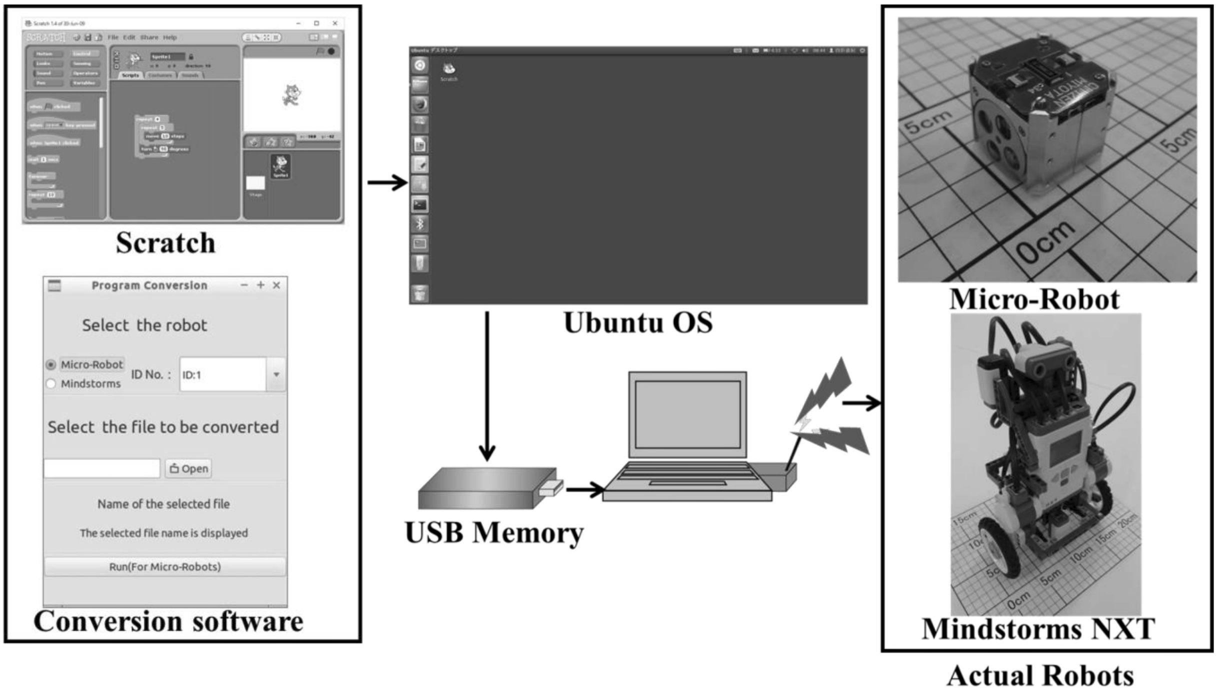

Fig. 1. A schematic view of the teaching tool.

environment called Scratch to resolve these issues. We created support software by which a control program created by Scratch is converted into the control program of the actual robot and gave lectures about programming experience using the software as a teaching tool. There are many practical reports on educational effects of using either Scratch which is one of established programming environments for beginners or actual robots which could obtain the participants' attention. However, this report includes the effects of lectures we performed using not only Scratch but also actual robots simultaneously to improve the participants' interests in matters relating to programming. The idea controlling some kinds of robots via Scratch as a common environment seems to be a unique way because many robots used as teaching tools have own development environment. Therefore, since participants can choose their favorite robot to check self-made program created by Scratch, participants' interests might be more heightened.

We had the participants involved complete a questionnaire focused on their level of interest in ICT to determine whether or not this was affected by the use of actual robots in the class. In this paper, we report not only the design of the class, which was based on experience from previous work [4], but also on its effects on the participants. In this way, we link the present findings in the Japanese context to those of a number of researchers across the world, who have pointed out that the use of actual robots is an effective tool in programming education [5–14].

The paper is organized as follows: The teaching tool we used in the class is briefly described in Section 2. In Section 3, we present the design of our experience based programming lectures and the contents of the questionnaire. Statistical analyses of the questionnaire results are presented and discussed in Section 4. Finally, we present a conclusion in Section 5.

2. The teaching tool

By means of the teaching tool we developed, two kinds of actual robots, namely Micro-robot and LEGO Mindstorms NXT, can be controlled via programs developed with Scratch. All programs needed for the system are installed into the Ubuntu OS. As the Ubuntu OS is bootable from USB memory, this system is easy to take anywhere. A schematic view of the system is shown in Fig. 1. The primary parts of the system are discussed in turn below.

- **Scratch:** Scratch aims to develop learners' enjoyment of computer programming, and is provided as free software by the Lifelong Kindergarten Group [15] within the MIT Media Lab [16][1]. A feature of this software is that programs for

[1] Although the current version of Scratch is 2.0, we used the old version 1.4, which allowed us to export a Scratch program as a text file that could be translated to the control codes for each actual robot using our software. Scratch version 1.4 is available from https://scratch.mit.edu/scratch_1.4/ (Accessed 18 October 2016).

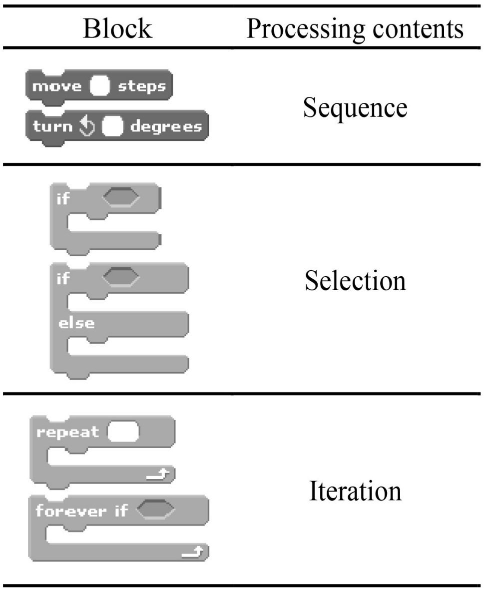

Fig. 2. Typical control blocks.

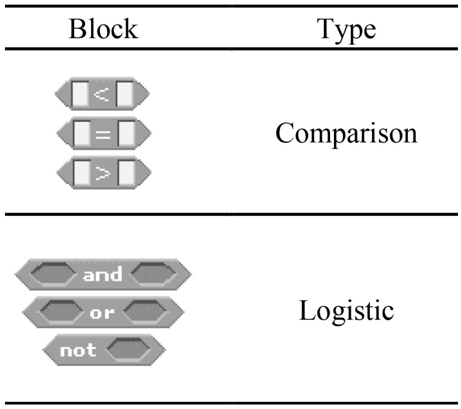

Fig. 3. Typical operator blocks.

controlling a picture image called "sprite" can be constructed by combining blocks containing instruction words, as shown in Figs. 2 and 3. The blocks will not stick together if the user attempts a program with incorrect grammar. This feature allows users to develop programs intuitively without first learning the grammar of the programming language. Thus, Scratch is particularly suitable for beginner programmers [17, 18].

- **The robots:** Two kinds of robots are included in the teaching tool. However, as our focus is on the general effect of using actual robots in such instruction, we emphasize that these are simply examples of actual robots.
  - Micro-robot: This robot is a cube of approximately three centimeters on each side, and was used in the mixed reality league in RoboCup's soccer competition [19]. As RoboCup aims to promote as well as develop robot engineering, applications of the Micro-robot as a teaching tool for information sciences were intended in addition to its use in soccer games [4, 20–22]. Thus, anyone can use the basic control codes presented by the league organizers and participants. The Micro-robot appears in the upper right of Fig. 1, and its specification is given in [4].
  - LEGO Mindstorms NXT: This is one of the most famous robots in programming education. Thus, it can be easily obtained and has been studied as a teaching tool for not only programming educations [23–32] but also Project Based Learnings (PBL) [33–35]. The manufacturer provides the development environment for controlling LEGO Mindstorms NXT. However, in our teaching tool, we use Scratch as the development environment in order to have a common interface for both robots (or all robots if others are to be included in future use). The specifications we use for this robot are basically according to the Embedded Technology Software Design Robot Contest (ET Robocon) of 2014. The ET Robocon is organized every year by the Japan Embedded Systems Technology Association [36], and is basically a line trace competition using Mindstorms. In the specification, movements of the robot are realized by two wheels connected to each driving motor and a tail wheel that prevents the robot from turning over. Although this robot is controlled by embedded programs in that specification, we use the wireless control system (see the explanation [37]) to save embedding times. The LEGO Mindstorms NXT robot is shown in the lower right part of Fig. 1.

  Note that the competitions using the above two robots were organized at national and international levels. It has been reported that interest in participation in such competitions is a strong motivation for studying programming [38, 39], and this was our reason for using these particular robots in this study.
- **Conversion software:** The GUI software we developed forms a core part of our teaching tool. This software converts a program made with Scratch into a program for controlling each robot. The conversion is realized by a matching and replacement algorithm, as follows:
  1. Instruction words in a text file exported from Scratch are searched.
  2. Sentences that do not correspond to control blocks are removed and header sentences inserted (e.g., import header files of required functions).

Table 1. Details of the participants in each group

	Only Scratch		Scratch and Robots	
	male	female	male	female
1st grade	0	0	38	9
2nd grade	15	3	3	8
3rd grade	35	8	0	0
Unknown	2		0	
total	63		58	

3. If command sentences corresponding to the control blocks are found, these command sentences are replaced by suitable control ones for each robot.
4. As the positions of processing blocks in the text file exported from Scratch can be distinguished by the number of spaces from the top of each line, the spaces are counted in order to determine the effective positions of processing blocks and suitable sets of curly brackets are inserted.
5. The control code for each robot is exported.

As the algorithm used in this software is applicable to any robot of which the control functions are available, other kinds of robots can simply be added to this system.

Our idea to make control codes for some kinds of actual robots by common interface i.e. Scratch, could ensure enough time to make the code without detail explanation of grammar of programming languages. In addition, participants can program control codes for every robot via a Scratch environment even if the number of selectable robots which are used to check the operation of participants' codes are increased. This point brings educational benefits (i.e., Reduce teaching time of grammar of programming languages, and increase practice time of programming) to participants and teachers.

3. Procedures

3.1 Experience based lectures

We conducted experience based lectures with high school students aged 15 to 18 years, one with and one without the use of actual robots as described above. The majority of the participants were beginners to computer programming. Whereas some may have had some personal experience of programming, they had had no official opportunity to learn it at school. The details of each group are given in Table 1, where "Only Scratch" denotes the group who used Scratch without controlling actual robots (N = 63), and "Scratch and Robots" indicates the group who used Scratch and actual robots (N = 58). As the lectures were given to the groups in class, participants carried out their programming on shared PCs, with four or five participants to a PC. The activities to be conducted were explained by means of a slide presentation, without a textbook. The design of the experience based lecture is shown in Fig. 4.

Note that the participants in the Only Scratch group, who did not use actual robots, learned Scratch programming through solving exercises. In contrast, the participants who had actual robots available were able to see the motions of the robot controlled by the programs they had created, as well as doing the exercises.

3.2 The questionnaire

The participants of both groups completed a questionnaire before and after their respective lectures. The aim was to determine the effects of the use of robots on the level of interest in ICT among these high school beginner programmers, as is clear from the wording of the questionnaire items in Tables 2 and 3. For each questionnaire item, participants were required to indicate their degree of agreement with the given statement, with 1 = "strongly disagree" and 4 = "strongly agree." Note that the same questionnaire items were used both before and after the lecture, and for both groups. Thus, the results may inform us as to changes in the participants' levels of interest following the lectures with and without the use of robots. Participants were also asked to indicate their subject preferences before the lectures, answering the question "What subjects do you like?" by selecting as many of the given subjects as they wished. The statistical analysis of the data is presented in the following section.

4. Analysis and discussion

The participants' responses to the questionnaire items are given in Tables 2 and 3, for the Only Scratch and Scratch and Robots groups, respectively. Certain participants did not complete the questionnaire in full, and their data were excluded from the analysis. The results indicate positive learner responses to the lecture content. In particular, over 80% of participants answered "Strongly agree" or "Agree" for items A1 (interest in computer operation), A/B2 (importance of computer knowledge), A/B6 (predilection for practical work in information science classes), and B9 (enjoyment of the class).

In terms of subject preferences, we began with a statistical test of the significance of subject preference to determine whether or not the two groups (with and without the actual robots) could be distinguished. The groups differed significantly in terms of Society and Art, but no further differences were significant, including those for science-related sub-

Time	Participant activities	Teacher instruction and assistance
Pre-test 5 minutes	● Complete the questionnaire	✧ Explain questionnaire items ✧ Allow participants to complete the questionnaire
	<u>GOAL: Create a program with Scratch that controls sprites (and robots)</u>	
Introduction 10 minutes	● Open Scratch	✧ Help participants to activate Scratch ✧ Explain programming methods using Scratch
	<u>Example: Create a program that makes the sprite move forward</u>	
	● Create a program composed of "move ○ steps" blocks, as shown in Fig. 2.	✧ Have participants consider the difference between a method of changing variable ○ in the block and a method of stacking blocks
Build-up 25 minutes	<u>Exercise 1: Create a program that makes the sprite draw a square</u>	
	● Create a program composed of "move ○ steps" and "turn ○ degrees" blocks as shown in Fig. 2 ● Simplify the program using "repeat ○" blocks, as shown in Fig. 2	✧ Have participants find the program that can draw the square by using four step- and turn-blocks ✧ Introduce the use of repeat-block comparing with stacking of sequence-blocks
	<u>Exercise 2: Create a program that makes the sprite draw an equilateral triangle</u>	
	● Create a program using sequence and iteration blocks, as shown in Fig. 2	✧ Allow participants to discover that a variable of the rotation angle is not an inner angle (60 deg.) but an exterior angle (120 deg.) of an equilateral triangle
Development 20 minutes	<u>Exercise 3: Create a program that makes the sprite draw a pentacle star</u>	
	● Derive an angle of the pentacle star ● Create the program using sequence and iteration blocks, as shown in Fig. 2	✧ Allow participants to discover that a variable of the rotation angle for drawing a pentacle star is 144 deg.
	(Control of the actual robots using the programs created by participants with Scratch are demonstrated in the case of the "Scratch and Robots" group)	
Summary 5 minutes	● Close Scratch	✧ Explain selection blocks not used in the class[1] ✧ Explain the fact that all programs can be created by using Sequence, Selection, and Iteration procedures
Post-test 5 minutes	● Complete the questionnaire	✧ Allow participants to complete the questionnaire ✧ Collect the questionnaires

[1] We acknowledge that further work is needed to develop a suitable curriculum, including a focus on selection procedures, as an understanding of the selection procedure and its combination with iteration procedures are absolutely imperative to allow more complex robot control. One idea worthy of pursuit is the use of Mindstorms' sensor, e.g., if Mindstorms passes over a line and detects this event via his sensor, he stops moving as a result of a selection procedure.

Fig. 4. The design of the experience based lecture.

jects (see Table 4). These results lead to the assumption that the two groups were identical in terms of their preferences for science-related subjects.

Under this assumption, we tested the null hypothesis "For the same question, the difference of mean scores between before and after lectures is 0" and the alternative hypothesis "For the same question, the difference of mean scores between before and after lectures is not 0" in order to determine whether or not participants' views about and interest in ICT

Table 2. Questionnaire results: Only Scratch (N = 63)

		Item	Strongly agree 4	Agree 3	Disagree 2	Strongly disagree 1
Before the lecture	A1	I like computer operation	34(53.97%)	20(31.75%)	8(12.70%)	1(1.59%)
	A2	I acknowledge the importance of absorbing knowledge about computers	41(65.08%)	20(31.75%)	2(3.17%)	0(0.00%)
	A3	I have the desire to pursue an ICT-related vocation	17(26.98%)	31(49.21%)	11(17.46%)	4(6.35%)
	A4	I am interested in application software	21(33.33%)	29(46.03%)	9(14.29%)	4(6.35%)
	A5	I am interested in computer hardware	18(28.57%)	24(38.10%)	19(30.16%)	2(3.17%)
	A6	I prefer practical work to lecture in classes of information sciences	37(58.73%)	20(31.75%)	4(6.35%)	2(3.17%)
	A7	I acknowledge the importance of computer knowledge in daily life	35(55.56%)	25(39.68%)	3(4.76%)	0(0.00%)
	A8	I regard computer knowledge to be useful for the future	44(69.84%)	16(25.40%)	3(4.76%)	0(0.00%)
	A9	I can keep up in information science classes	18(28.57%)	32(50.79%)	9(14.29%)	4(6.35%)
After the lecture	B1	I understood today's lecture	29(46.03%)	28(44.44%)	6(9.52%)	0(0.00%)
	B2	I acknowledge the importance of absorbing knowledge about computers	40(63.49%)	21(33.33%)	2(3.17%)	0(0.00%)
	B3	I have the desire to pursue an ICT-related vocation	23(36.51%)	28(44.44%)	10(15.87%)	2(3.17%)
	B4	I am interested in application software	29(46.03%)	26(41.27%)	7(11.11%)	1(1.59%)
	B5	I am interested in computer hardware	25(39.68%)	22(34.92%)	15(23.81%)	1(1.59%)
	B6	I prefer practical work to lecture in classes of information sciences	43(68.25%)	15(23.81%)	4(6.35%)	1(1.59%)
	B7	I acknowledge the importance of computer knowledge in daily life	42(66.67%)	20(31.75%)	1(1.59%)	0(0.00%)
	B8	I regard computer knowledge as useful for the future	42(66.67%)	18(28.57%)	3(4.76%)	0(0.00%)
	B9	I had fun during today's class	39(61.90%)	20(31.75%)	4(6.35%)	0(0.00%)
	P1	What classes do you like? (Check all that apply)	Japanese	Mathematics	Society	Physical Education
			16(25.40%)	23(36.51%)	8(12.70%)	31(49.21%)
			English	Sciences	Technology and Home Economics	Art
			12(19.05%)	14(22.22%)	6(9.52%)	8(12.70%)

changed following the lectures. Statistical analysis showed a significant increase for items A/B4 (interest in application software) and A/B5 (interest in computer hardware) for the Scratch and Robot group, but no statistically significant differences for the Only Scratch group, as is clear from Tables 5 and 6. Thus, the use of the robots in the experience based lectures appears to have been effective in increasing participants' interest in certain aspects of ICT.

Furthermore, we found a statistically significant difference between the effect of the robots on science-minded and non-science-minded participants (distinguished on the basis of their answers regarding subject preferences. i.e., it depends on whether or not the participant chose science as a favorite subject). Specifically, the data in Table 8 show that the non-science-minded students in the Scratch and Robots group differed significantly in terms of A/B5, whereas the use of the robots had no significant effect on the other students (see Tables 7, 9, and 10). Thus, this analysis indicates that the use of the robots in these experience based program-

Table 3. Questionnaire results: Scratch and Robots (N = 58)

		Item	Response			
			Strongly agree	Agree	Disagree	Strongly disagree
			4	3	2	1
Before-Lecture	A1	I like computer operation	14(24.14%)	34(58.62%)	10(17.24%)	0(0.00%)
	A2	I acknowledge the importance of absorbing knowledge about computers	33(56.90%)	24(41.38%)	1(1.72%)	0(0.00%)
	A3	I have the desire to pursue an ICT-related vocation	9(15.52%)	28(48.28%)	17(29.31%)	4(6.90%)
	A4	I am interested in application software	9(15.52%)	32(55.17%)	16(27.59%)	1(1.72%)
	A5	I am interested in computer hardware	9(15.52%)	32(55.17%)	16(27.59%)	1(1.72%)
	A6	I prefer practical work to lecture in classes of information sciences	25(43.10%)	28(48.28%)	4(6.90%)	1(1.72%)
	A7	I acknowledge the importance of computer knowledge in daily life	35(60.34%)	21(36.21%)	2(3.45%)	0(0.00%)
	A8	I regard computer knowledge to be useful for the future	35(60.34%)	22(37.93%)	1(1.72%)	0(0.00%)
	A9	I can keep up in information science classes	9(15.52%)	39(67.24%)	9(15.52%)	1(1.72%)
After-Lecture	B1	I understood today's lecture	27(46.55%)	30(51.72%)	1(1.72%)	0(0.00%)
	B2	I acknowledge the importance of absorbing knowledge about computers	34(58.62%)	23(39.66%)	1(1.72%)	0(0.00%)
	B3	I have the desire to pursue an ICT-related vocation	12(20.69%)	30(51.72%)	14(24.14%)	2(3.45%)
	B4	I am interested in application software	14(24.14%)	36(62.07%)	8(13.79%)	0(0.00%)
	B5	I am interested in computer hardware	15(25.86%)	35(60.34%)	8(13.79%)	0(0.00%)
	B6	I prefer practical work to lecture in classes of information sciences	33(56.90%)	22(37.93%)	3(5.17%)	0(0.00%)
	B7	I acknowledge the importance of computer knowledge in daily life	34(58.62%)	22(37.93%)	2(3.45%)	0(0.00%)
	B8	I regard computer knowledge as useful for the future	37(63.79%)	20(34.48%)	1(1.72%)	0(0.00%)
	B9	I had fun during today's class	47(81.03%)	11(18.97%)	0(0.00%)	0(0.00%)
	P1	What classes do you like? (Check all that apply)	Japanese	Mathematics	Society	Physical Education
			13(22.41%)	24(41.38%)	16(27.59%)	31(53.45%)
			English	Sciences	Technology and Home Economics	Art
			8(13.79%)	21(36.21%)	11(18.97%)	17(29.31%)

Table 4. Statistical significance of subject preferences across the two groups (N = 63; 58)

Subjects which Respondent Likes	Only Scratch	Scratch + Robot	Z_0
	Response	Response	
Japanese	16(25.40%)	13(22.41%)	-0.3840
Mathematics	23(36.51%)	24(41.38%)	0.5492
Sciences	14(22.22%)	21(36.21%)	1.6949
Society	8(12.70%)	16(27.59%)	2.0517*
English	12(19.05%)	8(13.79%)	-0.7774
Physical Education	31(49.21%)	31(53.45%)	0.4664
Technology and Home Economics	6(9.52%)	11(18.97%)	1.4931
Art	8(12.70%)	17(29.31%)	2.2547*

Double asterisk (**) and single asterisk (*) indicate significance at 1% and 5% by significant testing.

Table 5. Significance (t-test) of before vs. after differences: Only Scratch (N = 63)

Item			Mean	Variance	t
A2/B2	I acknowledge the importance of absorbing knowledge about computers	Before	3.6190	0.5515	-0.1611
		After	3.6032	0.5547	
A3/B3	I have the desire to pursue an ICT-related vocation	Before	2.9683	0.8418	1.1931
		After	3.1429	0.8003	
A4/B4	I am interested in application software	Before	3.0635	0.8590	1.7813
		After	3.3175	0.7367	
A5/B5	I am interested in computer hardware	Before	2.9206	0.8482	1.3780
		After	3.1270	0.8326	
A6/B6	I prefer practical work to lecture in classes of information sciences	Before	3.4603	0.7583	0.9850
		After	3.5873	0.6871	
A7/B7	I acknowledge the importance of computer knowledge in daily life	Before	3.5079	0.5922	1.4472
		After	3.6508	0.5130	
A8/B8	I regard computer knowledge to be useful for the future	Before	3.6508	0.5725	-0.3092
		After	3.6190	0.5800	

Double asterisk (**) and single asterisk (*) indicate significance at 1% and 5% by significant testing.

Table 6. Significance (t-test) of before vs. after differences: Scratch and Robots (N = 58)

Item			Mean	Variance	t
A2/B2	I acknowledge the importance of absorbing knowledge about computers	Before	3.5517	0.5355	0.1737
		After	3.5690	0.5335	
A3/B3	I have the desire to pursue an ICT-related vocation	Before	2.7241	0.8120	1.1768
		After	2.8966	0.7652	
A4/B4	I am interested in application software	Before	2.8448	0.6959	2.1247*
		After	3.1034	0.6124	
A5/B5	I am interested in computer hardware	Before	2.8448	0.6959	2.2486*
		After	3.1207	0.6234	
A6/B6	I prefer practical work to lecture in classes of information sciences	Before	3.3276	0.6854	1.5863
		After	3.5172	0.5995	
A7/B7	I acknowledge the importance of computer knowledge in daily life	Before	3.5690	0.5654	-0.1639
		After	3.5517	0.5673	
A8/B8	I regard computer knowledge to be useful for the future	Before	3.5862	0.5310	0.3520
		After	3.6207	0.5241	

Double asterisk (**) and single asterisk (*) indicate significance at 1% and 5% by significant testing.

Table 7. Significance (t-test): Non-science-minded, Only Scratch (N = 49)

Item			Mean	Variance	t
A2/B2	I acknowledge the importance of absorbing knowledge about computers	Before	3.6327	0.5281	0.0000
		After	3.6327	0.5281	
A3/B3	I have the desire to pursue an ICT-related vocation	Before	3.0204	0.8034	0.8822
		After	3.1633	0.7997	
A4/B4	I am interested in application software	Before	3.0612	0.8268	1.6955
		After	3.3265	0.7184	
A5/B5	I am interested in computer hardware	Before	2.8776	0.8571	1.1920
		After	3.0816	0.8376	
A6/B6	I prefer practical work to lecture in classes of information sciences	Before	3.4286	0.7906	0.9428
		After	3.5714	0.7071	
A7/B7	I acknowledge the importance of computer knowledge in daily life	Before	3.5102	0.5818	1.1297
		After	3.6327	0.4871	
A8/B8	I regard computer knowledge to be useful for the future	Before	3.6939	0.5084	-0.7758
		After	3.6122	0.5329	

Double asterisk (**) and single asterisk (*) indicate significance at 1% and 5% by significant testing.

ming classes was more effective for the participants who did not choose science, as their interest in computer hardware increased.

Next, we considered the significance of correlations across items A1–A9 and B1–B9, which reflect participants' responses before and after the lectures. In Tables 11 and 12, we report the correlation coefficients obtained for each item with an indication of bidirectional significance for the Only Scratch and Scratch and Robot groups, respectively. These tables also reflect the results of tests of significance (non-correlation testing) with the

Table 8. Significance (*t*-test): Non-science-minded, Scratch and Robots (*N* = 37)

Item			Mean	Variance	*t*
A2/B2	I acknowledge the importance of absorbing knowledge about computers	Before	3.4865	0.5588	0.4165
		After	3.5405	0.5575	
A3/B3	I have the desire to pursue an ICT-related vocation	Before	2.6216	0.7941	1.2519
		After	2.8378	0.6877	
A4/B4	I am interested in application software	Before	2.7297	0.6932	1.6697
		After	2.9730	0.5521	
A5/B5	I am interested in computer hardware	Before	2.8108	0.7007	2.0065*
		After	3.1081	0.5669	
A6/B6	I prefer practical work to lecture in classes of information sciences	Before	3.2432	0.6833	1.2629
		After	3.4324	0.6028	
A7/B7	I acknowledge the importance of computer knowledge in daily life	Before	3.5405	0.5575	-0.6255
		After	3.4595	0.5575	
A8/B8	I regard computer knowledge to be useful for the future	Before	3.5405	0.5575	0.2191
		After	3.5676	0.5022	

Double asterisk (**) and single asterisk (*) indicate significance at 1% and 5% by significant testing.

Table 9. Significance (*t*-test): Science-minded, Only Scratch (*N* = 14)

Item			Mean	Variance	*t*
A2/B2	I acknowledge the importance of absorbing knowledge about computers	Before	3.5714	0.6462	-0.2915
		After	3.5000	0.6504	
A3/B3	I have the desire to pursue an ICT-related vocation	Before	2.7857	0.9750	0.8355
		After	3.0714	0.8287	
A4/B4	I am interested in application software	Before	3.0714	0.9972	0.6194
		After	3.2857	0.8254	
A5/B5	I am interested in computer hardware	Before	3.0714	0.8287	0.6855
		After	3.2857	0.8254	
A6/B6	I prefer practical work to lecture in classes of information sciences	Before	3.5714	0.6462	0.2954
		After	3.6429	0.6333	
A7/B7	I acknowledge the importance of computer knowledge in daily life	Before	3.5000	0.6504	0.8983
		After	3.7143	0.6112	
A8/B8	I regard computer knowledge to be useful for the future	Before	3.5000	0.7596	0.5024
		After	3.6429	0.7449	

Double asterisk (**) and single asterisk (*) indicate significance at 1% and 5% by significant testing.

Table 10. Significance (*t*-test): Science-minded, Scratch and Robots (*N* = 21)

Item			Mean	Variance	*t*
A2/B2	I acknowledge the importance of absorbing knowledge about computers	Before	3.6667	0.4830	-0.3147
		After	3.6190	0.4976	
A3/B3	I have the desire to pursue an ICT-related vocation	Before	2.9048	0.8309	0.3575
		After	3.0000	0.8944	
A4/B4	I am interested in application software	Before	3.0476	0.6690	1.3950
		After	3.3333	0.6583	
A5/B5	I am interested in computer hardware	Before	2.9048	0.7003	1.0808
		After	3.1429	0.7270	
A6/B6	I prefer practical work to lecture in classes of information sciences	Before	3.4762	0.6796	0.9788
		After	3.6667	0.5774	
A7/B7	I acknowledge the importance of computer knowledge in daily life	Before	3.6190	0.5896	0.5364
		After	3.7143	0.5606	
A8/B8	I regard computer knowledge to be useful for the future	Before	3.6667	0.4830	0.2949
		After	3.7143	0.5606	

Double asterisk (**) and single asterisk (*) indicate significance at 1% and 5% by significant testing.

null hypothesis "the correlation coefficient is 0" and the alternative hypothesis "the correlation coefficient is not 0." The results show a significant correlation between the items related to the importance of computer knowledge (A/B2 and A/B7) and that related to the usefulness of computers in the future (A/B8). A further significant correlation is shown in terms of interest in computers (A/B4 and A/B5). These correlations might indicate that the participants felt that both knowledge of and interest in computers will be useful in their futures.

Further correlation analysis shows that responses

Table 11. Correlation coefficients across all items and significance (t-test): Only Scratch (N = 63)

CoC	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1									
A2	0.3847**								
A3	0.6402**	0.4947**							
A4	0.4500**	0.3583**	0.5159**						
A5	0.4663**	0.5205**	0.3578**	0.6048**					
A6	0.6608**	0.2332	0.6549**	0.5239**	0.4088**				
A7	0.4171**	0.4538**	0.4858**	0.3795**	0.4347**	0.4766**			
A8	0.4890**	0.6447**	0.5121**	0.4722**	0.4403**	0.4506**	0.7219**		
A9	0.5432**	0.1539	0.2769*	0.4496**	0.2987*	0.4225**	0.1142	0.3502**	
B1	0.1992	0.2126	0.0506	0.1301	0.2852*	0.1108	0.1795	0.2164	0.1666
B2	0.3591**	0.7105**	0.3180*	0.2907*	0.4462**	0.1728	0.4270**	0.5724**	0.1186
B3	0.5116**	0.3811**	0.6293**	0.3385**	0.1833	0.4214**	0.1167	0.3219*	0.3596**
B4	0.5219**	0.3422**	0.4586**	0.6813**	0.4281**	0.3982**	0.3268**	0.4966**	0.4386**
B5	0.4762**	0.6339**	0.2820*	0.5298**	0.7225**	0.2636*	0.3577**	0.5006**	0.3925**
B6	0.7278**	0.2169	0.5068**	0.3731**	0.3027*	0.7729**	0.4045**	0.4478**	0.4345**
B7	0.1786	0.2633*	-0.0261	0.0511	0.2318	0.1711	0.4340**	0.4568**	0.0509
B8	0.4019**	0.4970**	0.3382**	0.2759*	0.2654*	0.2585*	0.4315**	0.6616**	0.3133*
B9	0.1244	0.3005*	0.0967	0.2065	0.3325**	0.1342	0.1866	0.2387	0.1397

CoC	B1	B2	B3	B4	B5	B6	B7	B8
A1								
A2								
A3								
A4								
A5								
A6								
A7								
A8								
A9								
B1								
B2	0.3163*							
B3	0.1758	0.3114*						
B4	0.2907*	0.4316**	0.4142**					
B5	0.3572**	0.5648**	0.3838**	0.6169**				
B6	0.2327	0.2828*	0.4316**	0.4860**	0.4032**			
B7	0.1455	0.4120**	0.0449	0.2554*	0.3320**	0.2709*		
B8	0.2871*	0.4750**	0.3276**	0.4008 *	0.4692**	0.4491**	0.4130**	
B9	0.5282**	0.3250**	0.2289	0.3512**	0.3317**	0.2454	0.3174*	0.3308**

Double asterisk (**) and single asterisk (*) indicate significance at 1% and 5% by significant testing.

to item A9, which targets comprehension of information science, correlated significantly at the 5% level with items B3 (interest in ICT employment), B4 (interest in hardware), B5 (interest in software), B6 (predilection for practical work in information science classes) and B8 (future usefulness of ICT knowledge) in the Only Scratch group. This correlation suggests that responses to these items depended to an extent on participants' understanding of information science classes.

In contrast, in the Scratch and Robot group, there was no significant correlation between item A9 and items B3–B6 and B8, as shown in Table 12. Thus, in this group, the interests expressed in B3–B6 and B8 did not depend on the participants' understanding of information science classes. In addition, Fig. 5 shows that the answers "Strongly agree" and "Agree" were most likely in this group for items B3–B6 and B8, regardless of responses to item A9. Thus, it is possible that the recognition of the importance of ICT did not depend on these Scratch and Robot participants' level of understanding of information science classes.

The above discussion suggests that the use of actual robots in programming classes for students such as these high school beginner programmers may be effective in raising their interest in ICT, irrespective of their learning interests and information science background.

5. Conclusion

The teaching tool allowing the control of actual robots via Scratch was developed in the present study to allow participants to feel a sense of accomplishment in programming in a limited time. Using the teaching tool, we performed two kinds of experience based programming lectures among high school learners who were beginner computer programmers. One class used only Scratch and

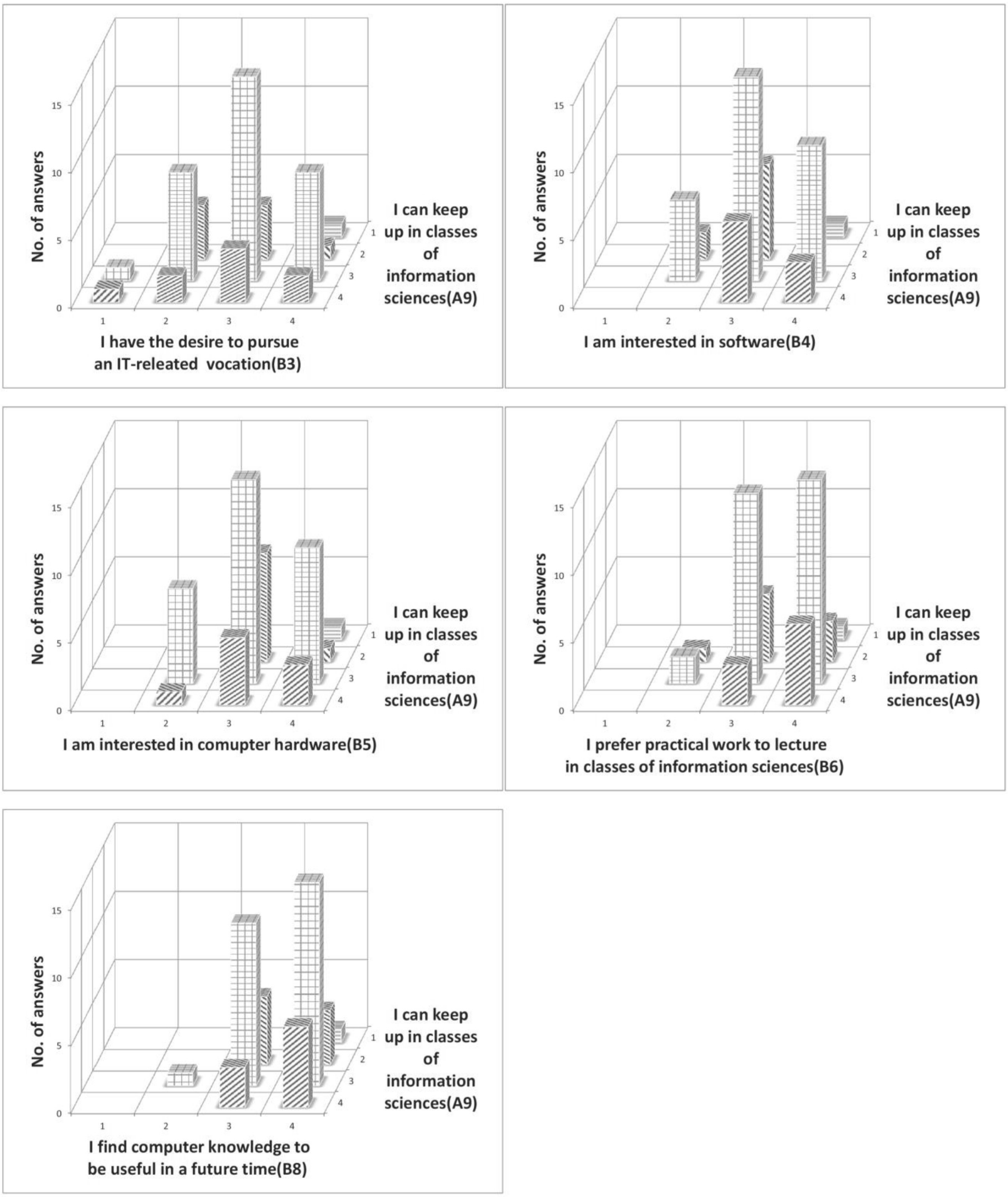

Fig. 5. Relationships between responses before lectures to item A9 and responses following lectures to B3, B4, B5, B6, and B8. The horizontal and vertical axes denote the scores for these items and the number of respondents, respectively.

controlled only sprites via their programs. The other used Scratch and actual robots, controlling both the sprites and the robots. In order to determine any changes in participants' ICT interests and concerns in the two groups, questionnaires were completed before and after the lecture. Statistical analysis of the questionnaire data showed that the use of actual robots in the programming class was effective for the participants, especially for the non-science-minded students (who did not choose science as a favorite subject in the questionnaire), as well as those who had a different understanding of information sciences that they were taught in high school.

Table 12. Correlation coefficients across all items and significance (*t*-test): Scratch and Robots ($N = 58$)

CoC	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1									
A2	0.2942*								
A3	0.3049*	0.3965**							
A4	0.4150**	0.3279*	0.4507**						
A5	0.3759**	0.1867	0.5128**	0.6015**					
A6	0.6225**	0.4549**	0.1022	0.2188	0.1084				
A7	0.4196**	0.4515**	0.5007**	0.3621**	0.4067**	0.2802*			
A8	0.3921**	0.6319**	0.4630**	0.2980 *	0.3930**	0.3308*	0.8564**		
A9	0.3129*	0.3224*	0.0156	0.1093	-0.0126	0.4397**	0.0569	0.1690	
B1	0.2136	0.4072**	0.2894*	0.3312*	0.2841*	0.1665	0.2438	0.4170**	0.3114*
B2	0.2918*	0.6628**	0.4091**	0.3365**	0.3837**	0.3929**	0.5364**	0.6599**	0.1664
B3	0.3345*	0.1845	0.6873**	0.2658*	0.2329	0.1326	0.3817**	0.2814*	-0.0446
B4	0.4257**	0.3579**	0.4112**	0.6558**	0.4500**	0.2104	0.2830*	0.2958*	0.1481
B5	0.4151**	0.2174	0.3788**	0.4887**	0.7314**	0.1933	0.3990**	0.3125*	-0.0344
B6	0.4959**	0.5710**	0.4064**	0.4061**	0.3219*	0.5625**	0.4623**	0.5189**	0.1432
B7	0.3256*	0.5974**	0.4885**	0.3984**	0.3540**	0.3843**	0.6997**	0.6547**	0.1049
B8	0.3382**	0.6338**	0.4919**	0.3649**	0.4130**	0.3520**	0.6819**	0.7501**	0.0670
B9	0.3272*	0.3371**	0.1074	0.2737*	0.2099	0.2980*	0.3341*	0.3717**	0.1159

CoC	B1	B2	B3	B4	B5	B6	B7	B8
A1								
A2								
A3								
A4								
A5								
A6								
A7								
A8								
A9								
B1								
B2	0.5654**							
B3	0.2864*	0.3186*						
B4	0.3911**	0.4610**	0.3976**					
B5	0.2555	0.4229**	0.3208*	0.6100**				
B6	0.4127**	0.5996**	0.2717*	0.3774**	0.3464**			
B7	0.3266*	0.5677**	0.3358**	0.3378**	0.3045*	0.7454**		
B8	0.4290**	0.6599**	0.2942*	0.3977**	0.4110**	0.6913**	0.8343**	
B9	0.4914**	0.5204**	0.1080	0.2273	0.2368	0.4211**	0.3182*	0.4933**

Double asterisk (**) and single asterisk (*) indicate significance at 1% and 5% by significant testing.

Thus, we achieved our goal of improving the participants' interest in ICT by offering the introductory class including practical work with control of actual robots by Scratch. Our findings reconfirmed those of other researchers regarding the effectiveness of such use of robots in beginner classes for computer programming.

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References

1. Ministry of Education Culture, Sports Science and Technology, *Elementary and Secondary Education*, http://www.mext.go.jp/en/policy/education/elsec/index.htm, Accessed 18 October 2016.
2. Ministry of Education Culture, Sports Science and Technology, *Higher education*, http://www.mext.go.jp/en/policy/education/highered/index.htm, Accessed 18 October 2016.
3. Ministry of Education Culture, Sports Science and Technology, *Technology Ministry's new curriculum guideline (Technology and Home Economics)*, http://www.mext.go.jp/component/a_menu/education/micro_detail/_icsFiles/afieldfile/2011/04/11/1298356_9.pdf, Accessed 18 October 2016.
4. T. Yamanishi, K. Sugihara, K. Ohkuma and K. Uosaki, Programming instruction using a micro robot as a teaching tool, *Comput. Appl. Eng. Educ.*, **23**, 2015, pp. 109–116.
5. O. Miglino, H. H. Lund and M. Cardaci, Robotics as an educational tool, *J. Interact. Learn. Res.*, **10**, 1999, pp. 25–47.
6. B. A. Maxwell and L. A. Meeden, Integrating robotics research with undergraduate education, *Intell. Syst. Their Appl. IEEE.*, **15**, 2000, pp. 22–27.
7. J. F. Martin and L. Chiang, Low cost vision system for an educational platform in artificial intelligence and robotics, *Comput. Appl. Eng. Educ.*, **10**, 2002, pp. 238–248.
8. D. Blank, D. Kumar, L. Meeden and H. Yanco, Pyro: A python-based versatile programming environment for teaching robotics, *J. Educ. Resour. Comput.*, **4**, 2004, p. 3.
9. Z. Dodds, L. Greenwald, A. Howard, S. Tejada and J. Weinberg, Components, curriculum, and community: Robots and robotics in undergraduate AI education, *AI Mag.*, **27**, 2006, p. 11.
10. F. Mondada, M. Bonani, X. Raemy, J. Pugh, C. Cianci, A. Klaptocz, S. Magnenat, J. C. Zufferey, D. Floreano and A.

Martinoli, The e-puck, a robot designed for education in engineering, *Proc. 9th Conf. Auton. Robot Syst. Compet.*, 2009, pp. 59–65.
11. B. Benson, A. Arfaee, C. Kim, R. Kastner and R. K. Gupta, Integrating embedded computing systems into high school and early undergraduate education, *Educ. IEEE Trans.*, **54**, 2011, pp. 197–202.
12. M. Hernando, R. Galán, I. Navarro and D. Rodríguez-Losada, Ten years of cybertech: The educational benefits of bullfighting robotics, *Educ. IEEE Trans.*, **54**, 2011, pp. 569–575.
13. N. Aliane, Teaching fundamentals of robotics to computer scientists, *Comput. Appl. Eng. Educ.*, **19**, 2011, pp. 615–620.
14. J. M. Rodríguez Corral, A. Morgado Estévez, D. Molina Cabrera, F. Pérez Peña, C. A. Amaya Rodŕguez and A. Civit Balcells, Application of Robot Programming to the Teaching of Object-Oriented Computer Languages, *Int. J. Eng. Educ.*, **32**, 2016, pp. 1823–1832.
15. Group of MIT Meda Lab., Lifelong Kindergarten, *Lifelong Kindergarten website*, http://llk.media.mit.edu/, Accessed 18 October 2016.
16. MIT Media Lab. website. https://www.media.mit.edu/, Accessed 18 October 2016.
17. D. J. Malan and H. H. Leitner, Scratch for budding computer scientists, in: *ACM SIGCSE Bull.*, 2007, pp. 223–227.
18. G. Fesakis, K. Serafeim, Influence of the familiarization with scratch on future teachers' opinions and attitudes about programming and ICT in education, in: *ACM SIGCSE Bull.*, 2009, pp. 258–262.
19. T. R. Federation, *Robocup*, http://www.robocup.org/, Accessed 18 October 2016.
20. R. da S Guerra, J. Boedecker, N. Mayer, S. Yanagimachi, Y. Hirosawa, K. Yoshikawa, M. Namekawa, and M. Asada, CITIZEN Eco-Be! League: bringing new flexibility for research and education to RoboCup, JSAI Tech. Rept. SIG-Challenge-0623-3, 2006, pp. 13–18.
21. R. Gerndt, C. Schridde and R. da Silva Guerra, On the aspects of simulation in the robocup mixed reality soccer systems, in: *Work. Int. Conf. Simulation, Model. Program. Auton. Robot*., 2008.
22. J. E. Anderson and J. Baltes, Using Mixed Reality to Facilitate Education in Robotics and AI., in: *FLAIRS Conf.*, 2009.
23. R. U. Pedersen, J. Nørbjerg and M. P. Scholz, Embedded programming education with lego mindstorms nxt using java (lejos), eclipse (xpairtise), and python (pymite), in: *Proc. 2009 Work. Embed. Syst. Educ.*, 2009, pp. 50–55.
24. S. H. Kim and J. W. Jeon, Introduction for Freshmen to Embedded Systems Using LEGO Mindstorms., *IEEE Trans. Educ.* **52**, 2009, pp. 99–108.
25. Y.-C. Lin, T.-C. Liu, Y.-C. Lin and H.-C. Yang, Creating a LEGO Robot as My Experiment Assistant: The Application of LEGO Mindstorms NXT in Elementary Science Education, in: *World Conf. E-Learning Corp. Gov. Heal. High. Educ.*, 2010, pp. 1977–1982.
26. C. Ball, F. Moller and R. Pau, The mindstorm effect: a gender analysis on the influence of LEGO mindstorms in computer science education, in: *Proc. 7th Work. Prim. Second. Comput. Educ.*, 2012, pp. 141–142.
27. R. Mason and G. Cooper, Mindstorms robots and the application of cognitive load theory in introductory programming, *Comput. Sci. Educ.* **23**, 2013, pp. 296–314.
28. H.-N. Liang, C. Fleming, K. L. Man and T. Tillo, A first introduction to programming for first-year students at a Chinese university using LEGO MindStorms, in: *Teaching, Assess. Learn. Eng. (TALE)*, 2013 IEEE Int. Conf., 2013, pp. 233–238.
29. A. Alvarez and M. Larranaga, Using LEGO mindstorms to engage students on algorithm design, in: *Front. Educ. Conf. 2013*, IEEE 2013, pp. 1346–1351.
30. M. Lykke, M. Coto, S. Mora, N. Vandel and C. Jantzen, Motivating programming students by Problem Based Learning and LEGO robots, in: *Glob. Eng. Educ. Conf. (EDUCON), 2014*, IEEE, 2014, pp. 544–555.
31. C. R. Fisher, Key-stage computing: Evaluating the suitability of Lego Mindstorms NXT 2.0 for use in early computer science education., *Discov. Invent. Appl.*, 2014.
32. M. Basso, G. Innocenti, Lego-bike: A challenging robotic lab project to illustrate rapid prototyping in the mindstorms/simulink integrated platform, *Comput. Appl. Eng. Educ.*, **23**, 2015, pp. 947–958.
33. Y.-T. Lee and S.-H. Jin, Rolling Discussion Technique for Facilitating Collaborative Engineering Design Activities, *Int. J. Eng. Educ.*, **30**, 2014, pp. 449–457.
34. Seungkeun Kim, H. Oh, J. C. A, Antonios Tsourdos, Using Hands-on Project with Lego Mindstorms in a Graduate Course, *Int. J. Eng. Educ.*, **32**, 2014, pp. 458–470.
35. Y. J. Jang and V. S. Yosephine, LEGO Robotics Based Project for Industrial Engineering Education, *Int. J. Eng. Educ.*, **32**, 2016, pp. 1268–1278.
36. J. E. S. T. Association, *Japan Embedded Systems Technology Association website*. http://www.jasa.or.jp/top/en/index.html.
37. T. Shikama, Development of Teaching Materials for Computer Programming Using a Robot Remotely Controlled by a PC through Wireless Communication, *IWIN2013 Proc.* 2013, pp. 133–139.
38. I. M. Verner and D. J. Ahlgren, Fire-Fighting Robot Contest: Interdisciplinary Design Curricula in College and High School, *J. Eng. Educ.*, **91**, 2002, pp. 355–359.
39. I. M. Verner and D. J. Ahlgren, Robot contest as a laboratory for experiential engineering education, *J. Educ. Resour. Comput.*, **4**, 2004, p.2.

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