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DEVELOPMENT AND APPLICATION OF ARDUINO-BASED EDUCATION PROGRAM FOR HIGH SCHOOL STUDENTS'

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ABSTRACT

As the importance of computing education has increased, Korea has strengthened its informatics courses in the 2015 revised national curriculum. However, there is no previous research on the newly added area of physical computing. In this study, Arduino was selected as a physical computing device to be used in school settings and developed educational program. In addition, the developed educational program was applied to high school students for 36 hours of instruction time. As a result of the application, there was no statistically significant change in the creative problem-solving ability of high school students who received the Arduino-based education. Upon investigating their opinions on Arduino-based education, the students who participated in the class said the Arduino-based education program was interesting and provided an accomplishment. However, they felt that the class was difficult because of factors such as design and debugging. Based on these results, it was confirmed that consideration of teaching-learning methods, teaching materials, and activities is necessary for high school students to teach physical computing.

Keywords: *Arduino, Education program, High school student, Physical computing, Computing Education, 2015 revised national curriculum*

1. INTRODUCTION

The advancement of science and technology has facilitated the convergence between disciplines and promoted the emergence of new technologies. As a result, the impact of technology on people's lives has increased, with the effects pervading various aspects of daily living, such as society, culture, and the economy. These changes have facilitated unimaginable transformations in people's lives, jobs, and relationships. The World Economic Forum described this change as the fourth industrial revolution, and predicted that it would be led by artificial intelligence, robots, biotechnology, and the Internet of Things [1]. To nurture human resources that are well adapted to the fourth industrial revolution, schools around the world have introduced computing education [2].

Korea has made computing education a compulsory subject in its 2015 revised national curriculum for elementary (practical arts) and middle school (informatics) [3,4,5]. The content of the revised informatics curriculum consists of the courses Information Culture, Data and Information, Problem Solving and Programming, and Computing System. In Computing System, a new physical computing domain has been added to enhance the ability to implement a computing system for solving real-life problems [6]. With this recent addition, the development of physical computing devices, such as Arduino as well as existing robots, has flourished [7].

Interest in physical computing has increased rapidly with the introduction of physical computing as a new domain in the 2015 revised national curriculum. By comparison, studies on the teaching of physical computing devices are scant [8,9,10]. Furthermore, the majority of previous studies have been conducted on elementary school students, whereas few have focused on middle school students, particularly general high school students [11,12].

This situation makes promoting physical computing education and computing education in the upcoming 2015 revision difficult. If students do not have a background in physical computing so that they can experience the problems of the real world through abstraction, algorithm, and

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automation principles, a gap between the knowledge learned and the real world can be formed. As a result, students' interest in computing education and the associated positive learning effects can be diminished. The awareness of and need for computing education can also be affected.

To address these issues, research on the development and application of educational programs for physical computing is needed. In this study, we developed and applied an educational program for high school students to effectively teach physical computing in the 2015 revised national curriculum. This study compared different physical computing devices, and a device called Arduino was chosen. The educational program created was applied on general high school students, and methods were developed to integrate the area of physical computing in the 2015 revised national curriculum.

2. BACKGROUNDS

2.1 2015 Revised National Curriculum

Until the 2009 revised national curriculum, interest in information curricula was low, and many students did not learn the topic in school. As the importance of computing education increased, however, the informatics curriculum changed. First, informatics became compulsory for all elementary and middle school students. In the high school curriculum, many students are now receiving computing education. The content of the curriculum now focuses on "Computational thinking," "Information culture literacy," and "Collaborative problem-solving ability" in order to cultivate human resources adapted to future society. In addition, a domain called "Computing system" was established to develop the ability to solve real life problems using a programming language. "Computing system" is aimed at creatively implementing a physical computing system for solving complex problems in various disciplines as well as efficient resource management methods [3,5]. In high school, there is an achievement standard to teach physical computing, construct a computing device with suitable hardware for problem solving, and develop a program to control the physical computing device [7].

2.2 Arduino

Physical computing means processing input data through a physical method based on digital technology and outputting it in a physical way [13]. It utilizes various sensors to input data, operates and controls input data through programming, and physically outputs data through an actuator. Arduino is a microcontroller developed in 2005 as a means of physical computing. Because it was built as an open source project, Arduino can modify schemes to develop other boards. In addition, various Arduino-related examples are being shared. Arduino can use a variety of input and output devices that are compatible with each other. Unlike existing physical computing devices, boards and modules have low cost [9].

2.3 Comparison of physical computing devices

In this study, we compared CodeIno, BitBlock, bitbrick, Orion board, and Arduino, all of which are widely used in physical computing tools (Lego is excluded because it is too expensive to be used in a school environment).

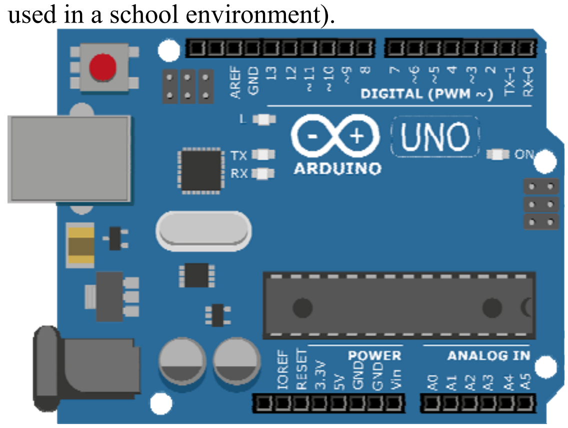

Figure 1: Arduino

The board was selected for comparison with the 2015 revised national curriculum. In the configuration of the board, Arduino and BitBlock do not have their own built-in sensor, while the CodeIno, bitbrick, and Orion boards contain sound or other sensors.

For external connection, CodeIno uses an audio jack, BitBlock uses a 3-pin connector, bitbrick uses a 4-pin connector, and the Orion board uses a dedicated device called RJ25.

While Arduino, CodeIno, and BitBlock are compatible with common connections, the bitbrick and Orion boards were not. All boards except Orion supported block-based and text-based languages. The Orion board only supported block-based programming languages.

The prices were compared based on the basic kit needed to practice the contents of the 2015 revised national curriculum. The cost of building the kit was $150 for CodeIno, BitBlock, and bitbrick and $220 for Orion. Arduino produced a similar kit for $120, which is not a significant variance from the other boards.

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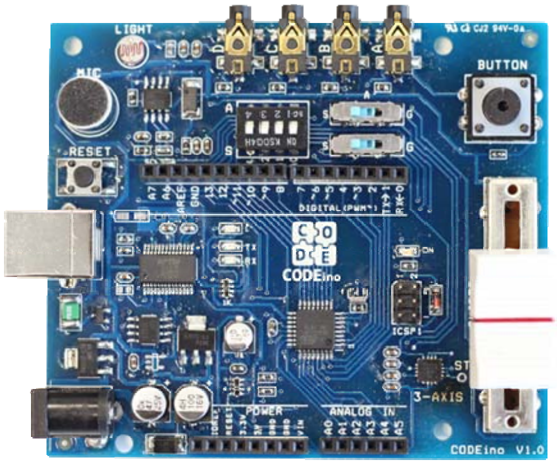

Figure 2: Codeino

However, if a compatible board were used, the teacher could build a kit for $60. Therefore, when the same practice was done at school, Arduino was cheaper than other boards, but there was a disadvantage in that the teacher had to order and make the kit.

In the 2015 revised national curriculum, informatics should use text-based programming in high schools [5]. It is also necessary to use various sensors and actuators to solve real life problems according to the curriculum. Finally, many students' physical computing practice requires consideration of the cost of physical computing devices.

Comparing devices, it was determined that Arduino is the most suitable device for high school physical computing because it was better than other boards in price, expandability, compatibility, and language. However, the inconvenience of sensor and actuator connection, and kit configuration placed it below other boards.

2.4 Literature Review

Son and Sohn (2014) developed an educational model integrating art, science, and information curricula based on the 2009 revised national curriculum to utilize Arduino for programming education. The researchers also applied lessons developed on the educational model to observe changes in the creativity, learning attitude, problem solving ability, learning interest, and learning flow of elementary school students. The results showed no change [14].

Seo and Kim (2016) developed learning content based on the Creative Problem Solving (CPS) model and applied it to elementary school students to observe creative personality changes. The results confirmed that the educational content based on Arduino helped solve the fixation

Figure 3: Orion board

phenomenon in the existing programming language and was effective for students' task commitment and curiosity enhancement [15].

Kim, Seo, and Kim (2016) investigated the change in creative problem-solving ability between a group that only learned Scratch and a group that linked Scratch and Arduino. They found that the latter group was more effective in improving creative problem-solving ability and improving the motivation element to continue the learning. Also, they found that it is necessary to select a considering stability, suitability, and economy for effective physical computing education [9].

Kim and Kim (2016) designed educational content to improve convergence competence and

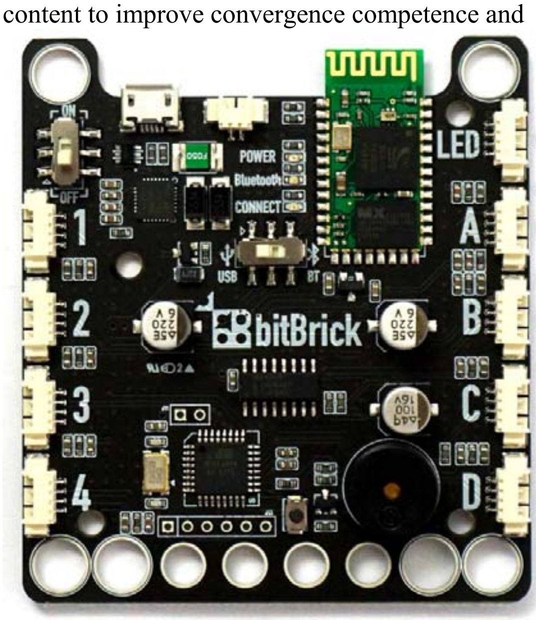

Figure 4: bitbrick

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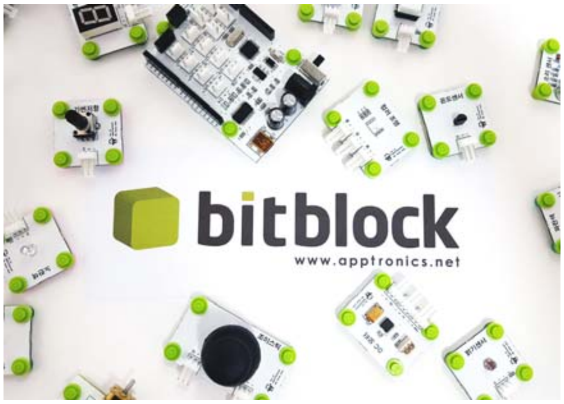

Figure 5: BitBlock

computing thinking and applied it to gifted mathematics/science middle school students. They confirmed that it was effective for improving interpersonal ability, creative personality, and integrated thinking [8].

Shim, Lee, and Suh (2014) designed an Arduino-based STEAM curriculum for gifted elementary school students to investigate their interest in computers, programming, and Arduino. As a result of the application of the curriculum, interest in programming and Arduino increased [16].

Choi and Kim (2016) designed programming education using App Inventor and Arduino and applied it to specialized high school students to investigate creative problem-solving ability and change in convergence thinking. Through the research, it was confirmed that the teaching of physical computing using App Inventor and Arduino improved convergence thinking, motivation, and divergent thinking of specialized high school students [11].

Table 1: Comparison of specifications between devices

		Arduino	CodeIno	BitBlock	bitbrick	Orion board
Configuration of board	Internal	None	- Button - Sensor (Light, Sound) - Slide	None	- Sensor (Sound)	- Sensor (Sound)
	External connection	- General	- General - Audio jack	- General - 3 pin connector	- 4 pin connector	- RJ-25
Programming language	Block based	- Scratch - S4A - modkit - Entry	- Scratch - Entry	- Scratch - mblock	- Exclusive lan guage - App inventor - Entry	- mblock
	Text based	- Sketch - Python	- Sketch	- Sketch	- Python	
Price (Similar kit)		$120 or $ 40 (use a compati ble board)	$150	$150	$150	$220

Kim and Choi (2016) developed a program for making an Arduino-based turtle ship and applied it to specialized high school students. The students who received the education program showed an improvement in their logical thinking and problem-solving abilities [12]. Previous studies have showed that an insufficient number of studies have been conducted on high school students.

3. METHOD

3.1 Research Subjects

This study was conducted with 20 female high school students. Ten students who did not participate in the pre- and post-test and educational program were excluded. There were 3 students in the first grade (30%) and 7 students in the second grade (70%). All students had prior programming experience. In addition, 9 students (90%) were experienced with C or C ++, and 2 students were experienced with Java (20%) and HTML (20%). The schools the research subjects attended were constantly conducting informatics education; therefore, all students had experience using text-based programming. Only one student had experience with a physical computing device; she had manipulated Arduino. Therefore, the research participants in this study understood the basics of programming and were ready for a physical computing device project without further explanation of the programming language, see Table 2.

3.2 Test Tool

This study developed an Arduino-based education program based on the 2015 revised national curriculum. This curriculum emphasizes the ability to design and implement a creative computing system to solve real world problems. Therefore, this study measured students' creative problem-solving abilities.

We utilized the "Simple Creative Problem-Solving Ability Test" used by Kong and Lee (2015). This tool consists of four sub-domains: self-confidence and independence; divergent thinking; critical and logical thinking; and motivational thinking. Each area included five items rated on a five-point Likert scale [17]. In addition, six questions were asked after the post-test to measure the opinions of the class. The questionnaire consisted of questions about positive and negative opinions of the class, successes and difficulties in class activities, and whether the classes related to Arduino were retaken and why.

3.3 Treatment

The education program was applied from April 19–July 14, 2016. During this period, students were given 12 lessons of three hours each. The program was developed based on Informatics of High School in the 2015 revised national curriculum, which guides students in building a physical computing system using a text-based programming language. Therefore, this educational program is based on Arduino, a physical computing device, and Sketch, a text-based programming language.

The proposed achievement standards of the 2015 revised national curriculum are "configure the computing device by choosing the suitable hardware for troubleshooting" and "write a program to control the operation of the physical computing device." In accordance with these standards, an educational program consisting of three areas was developed: Device Practice, Project, and Application. The device practice section teaches various input and output devices related to Arduino [5]. For Arduino device practice, Shim, Lee, and Suh (2014) developed a curriculum design methodology designed to help students effectively learn the lesson. [16]. Projects and applications were created to help students experience the process of solving problems using real life situations. The lesson was developed based on the learning model used by Choi and Kim (2016). Projects and application areas include problem situation analysis, which explores issues in various contexts by topic and collects relevant data [11].

Projects and application areas are designed not just to learn devices, but to provide students with experience in solving problems themselves. Therefore, the lessons are organized so that students can experience not only automation but also abstraction; Analysis-Definition-Create an idea-Design an algorithm-Implementation-Sharing and Debugging [18,19,20]. In the project area, the problem situation was solved using the car model made with the teacher. However, in the application area, students directly designed, produced, and programmed according to the problem situation and based on what they learned.

Table 2: Detailed information of research subjects (%)

Gender						
	Male		Female		Total	
Number of students	0 (0)		10 (100)		10 (100)	
Grade						
	10th		11st		Total	
Number of students	3 (30)		7 (70)		10 (100)	
Experience about programming						
	Yes		No		Total	
Number of students	10 (100)		0 (0)		10 (100)	
Programming Language						
	C/C++	JAVA	HTML	Scratch	Etc.	Total
Number of students	9 (90)	2 (20)	2 (20)	1 (10)	2(20)	10(100)
Experience about physical computing						
	Yes		No		Total	
Number of students	1 (10)		9 (90)		10 (100)	

4. RESULT

4.1 Results Of Application Of Arduino-Based Education Program

As a result of applying the Arduino-based education program, the creative problem-solving ability of high school students increased in the post-test (M = 66.00, SD = 7.63) compared to the pre-test (M = 65.30, SD = 6.58). However, the difference was not statistically significant (t = -1.65, p = .133). When examining the detailed areas, "self-confidence and independence" were higher in the post-test than in the pre-test, although the results were not statistically significant. The same results were found in "divergent thinking," "critical and logical thinking," and "motivational thinking." These results show that there is no statistically significant difference between the pre-test and the

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post-test of the creative problem-solving ability of high school students. Therefore, it was confirmed that the Arduino-based education program did not affect the creative problem-solving ability of the high school students.

In previous research, it was shown that the education program based on Arduino was effective in improving creative problem-solving ability for specialized high school students [11,12]. In addition, Kim & Choi (2016) reported that the interest and understanding of the class increased and that it was effective in improving the logical thinking ability and problem-solving ability [21]. Therefore, it was confirmed that the method of education using the Arduino should be different for the specialization high school and general high school students.

However, based on the results of this study, it was confirmed that the creative problem-solving ability did not improve even if the Arduino-based education program was applied to general high school students. Hwang, Mun, & Park (2016) conducted high school students' scientific education using physical computing device, and confirmed their confidence in solving problems through computing [22]. Based on these researches, it is necessary to study educational methods to improve the problem-solving ability of high school students by introducing education using physical computing devices in various subjects.

In this study, the effective teaching-learning method whose effectiveness was confirmed in the previous study was used for educational program development. This shows that the teaching-learning method used in previous research is not effective for general high school students. Kim, Seo, and Kim (2016) said that although physical computing can act as a reinforcement of learning, the effect of education decreases as the level of learning content increases [9]. It is also necessary to develop a teaching-learning plan suitable for the students' level for effective physical computing education for general high school students.

4.2 Students' Opinion Toward The Arduino-Based Education Program

When asked about the positive parts of the class, the most common answer provided by students was interest (46%). The students said the activities using Arduino were fun, and their interest in Arduino increased. The second most common opinion was achievement (31%). The students were very proud of what they were able to do themselves, and many said they wanted to make something using Arduino. Finally, students cited the problem-solving process (23%). They answered that the process of finding solutions through the design and programming of Arduino and the process of solving the questions were enjoyable.

Table 3: The results of comparison of pre- and post-test

Area		Test	*M*	*SD*	*t*	*P*
Total		Pre	65.30	6.58	-1.650	.133
		Post	66.00	7.63		
Sub	self-confidence and independence	Pre	14.00	1.94	-.451	.662
		Post	15.20	2.78		
	divergent thinking	Pre	15.00	2.05	.231	.823
		Post	15.50	2.46		
	critical and logical thinking	Pre	18.10	1.60	1.274	.235
		Post	18.00	1.63		
	motivational thinking	Pre	18.20	2.35	-.295	.775
		Post	17.30	2.11		

In the class that asked which activities they enjoyed, the answers included wireless car (36%), automatic driving car (29%), line tracing (29%), and none (7%). On one hand, students responded that they liked a variety of activities using the Arduino-based automobile module. On the other hand, none of the students felt that the IoT activities they programmed to solve real life problems were interesting. Some students answered that they were satisfied about the activities carried out in the project area, but none answered that they were good about the activities carried out in the application area. Unlike the project area, it is important to design a new physical computing device in the application area. Robot education also made it difficult for students to design, and this phenomenon appeared in the Arduino activity. Therefore, it was shown that students need to design a lesson that can reduce the burden on the design.

All students except one (90%) answered that "difficulty" was a negative aspect of the class. This included not only the difficulty of programming and the arduous design, but also the process of debugging when not in execution, the difficulty of inputting in English, and the application. One student (10%) responded that device management was difficult. This was particularly true when Arduino parts were broken. This opinion was similarly expressed in robot education.

On the question of what was difficult in class, students answered: design (40%), debugging (20%), theory (20%), and code (20%). In design, it was hard to know how and what to make. Debugging required an effort to find and fix errors in the code. Regarding theory, students felt that the process of learning the electrical and electronic knowledge necessary for the practice of Arduino was not fun. Difficulty in code indicated that it was challenging to input the text while testing the operation by connecting the sensor and the motor. These difficulties seem to have adversely affected students' creative problem-solving abilities [23].

Finally, 7 students (70%) said they would like to take the Arduino class again, while 3 students (30%) said they would not retake it. Those who responded positively expressed opinions such as, "I like to learn more about the process of making Arduino," "It's hard to think, but the process is fun," and "It was difficult but I was proud because I could see the result." Students confirmed that although they had difficulty with Arduino-based activities, they wanted to learn more because the found it interesting. all the students who chose not to retake the Arduino class said it was too difficult.

The education using Arduino held students' interest and gave them a sense of accomplishment. However, most students experienced difficulties in learning the program, and this difficulty negatively impacted the effectiveness of the lesson. To overcome these difficulties when designing the Arduino-based education program for general high school students, the following educational methods should be considered. First, consideration of teaching-learning methods is needed. The informatics of the 2015 revised national curriculum guides teachers through collaborative problem solving using team projects or pair programming. Project-based learning and pair programming help improve problem solving skills and can help students design and debug [24, 25, 26]. Therefore, it can overcome the difficulties of teaching physical computing using Arduino. Secondly, educational tools suitable for the environment should be selected. Students had difficulty learning the theory of electrical and electronic and design [2,27]. Other physical computing tools can connect without electrical and electronic knowledge. In addition, some educational tools cannot accomplish various projects, but they can reduce the burden of design that students experience. In this case, the economic burden is greater than that of Arduino, so it is possible to achieve effective teaching by choosing a suitable tool for the school environment [9]. Third, activities should be conducted at the appropriate level for the students. The students liked the activities based on the Arduino car, which had a small proportion of design [2]. Thus, if the teacher places appropriate activities in class according to the level of their students, students will receive effective physical computing education.

5. CONCLUSION

In this study, we developed an educational program using the Arduino device to integrate the teaching of physical computing in the 2015 revised national curriculum. The developed educational program was applied on high school students, and its effects on the students and these students' opinions were obtained. Several conclusions may be drawn from the results. First, the Arduino-based education program was not effective in improving the creative problem-solving skills of high school students. In contrast to previous studies, this study found no difference in the students' creative problem-solving abilities before and after the Arduino class. Second, the students were interested in and felt a sense of accomplishment in participating in the Arduino-based education program. However, in the physical computing education program, they encountered difficulty with design and debugging. Finally, appropriate teaching–learning methods, educational tools, and activity designs need to be developed for the program to be effective for high school students. Teachers can provide effective physical computing education by considering these factors vis-à-vis with the school environment and the students' learning level.

This study has the following limitations. First, the research subjects were 10 female high school students. The reason for the study is that it is due to the curriculum. In the 2015 revised national curriculum, an informatics curriculum is found essential in elementary and middle school, so it has been included as a general elective in the high school curriculum. This 2015 revised national curriculum will be introduced in 2018; the Arduino education program developed and applied in this study was made in 2016. Therefore, when the Arduino education program is applied, the 2009 revised national curriculum have been implemented, not the 2015 one, with the informatics curriculum included in the enrichment option. By the time of the 2009 revised national curriculum implementation, many high schools did not use the informatics curriculum, and as of the present study, few schools provide informatics education at the 36th grade. Therefore, in this study, the female high school students pursuing informatics education were required to proceed with the study. Furthermore, we did not proceed with the regular education course but instead implemented the after-school education program. Obtaining a large number of samples was therefore not possible. As a result, many students were interested in computer science and Arduino programming because only after-school curriculum students participated in this study.

Further studies should be conducted to solve these problems. First, establishing a control group composed of similar groups is necessary to verify the effectiveness of the education program based on Arduino. Observing the effects of applying the Arduino education program on both female and male high school students is also important. Research should use the Arduino-based education program on students who have little interest in programming and in Arduino and computer science, and then analyze the effects of this application. Finally, generalizing the results of this research through follow-up studies is needed.

The second limitation involves the physical computing device used. From a comparison of various boards, Arduino was selected in this study to be applied in the Korean educational context, and an educational program were developed using Arduino. However, the students who participated in this research stated that using Arduino was difficult because of a major problem in the Arduino-based education program. Although Arduino is cheaper and more compatible than other physical computing devices, it requires the process of designing the structure from the beginning to the end on the basis of one's knowledge of electricity and electronics. This process was difficult for the students, and it was a factor that hindered their development of self-efficacy and problem-solving ability.

Additional research is needed to resolve these difficulties. First, a comparison between physical computing devices is required. As the importance of physical computing education increases, various boards, as well as analyzed boards, are being developed. These boards have different internal and external connection methods, programming languages, types of sensors used, structures, and forms. This study examines the effects of these differences on the teaching of physical computing, and reflects them in the development of appropriate educational programs.

The last limitation is the availability in the school site. In this study, we developed the Arduino education program for the 36th classes and verified its effect on high school students. Although the number of informatics subjects increased in the 2015 revision curriculum, providing 36 classes of physical education courses in the regular education curriculum is difficult because there are other curriculums. It can be used in the after-school curriculum, club activities, and creative experiential activities, but the regular curriculum has limitations. In follow-up research, developing an educational program that can be used in the formal education curriculum and determining its effects on students are necessary. An education program for the regular education course, based on the topic that the students indicated in their feedback on the education program, should be created. Developing effective Arduino-based education programs by introducing appropriate teaching–learning methods, such as team projects, is also necessary to reduce the burden on design and debugging.

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