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Analyzing the Appropriateness of 'Functions' in the Physical Computing System Domain in Informatics

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Abstract

Background/Objectives: The informatics curriculum, which has been used with focus on ICT use since 2010, is changing. Information education is emphasizing the maker education in which learners make projects for themselves. **Methods/ Statistical Analysis:** As part of the maker education, personal computing was also added to the revised informatics curriculum, and 'functions' were proposed. **Findings:** This study had experts analyze whether the 'functions' proposed in the physical computing of the revised informatics curriculum are appropriate for accomplishing the intended purpose. The analysis result showed that designing and programming were appropriate functions in all domains consisting of suitability, importance and necessity, and cooperating was not playing the role as a function in any domain. Some viewed programming and implementing as similar functions, and managing were too conspicuously low in suitability and importance to be viewed as functions that can be expected after leaning in high schools. **Improvements/Applications:** The purpose of this study is to clearly propose functions to be performed after learning in future information education through analysis of physical computing 'functions'.

Keywords: Arduino Education, Informatics Curriculum, Information Education, Physical Computing, SW Education

1. Introduction

In Korea interest in information started with ICT use. The requirements in using ICT in elementary and middle schools are based on the ICT education operation guideline that was proposed in the 2000's. Then, in December 2005, a revised guideline was announced. Beyond interest in utilization, information science based on the principles of computer science started with the revised curriculum of 2007. The informatics curriculum was revised for the first time, and the curriculum was modified by the revisions in 2009 and 2011. Since 2010 overseas curriculums have been greatly changed with regard to information education. The UK established ICT as a 'computing' subject in 2013[1], and Japan announced the modified curriculum in 2010 and made 'information' a mandatory elective course in high schools[2] India documented CMC as the curriculum for each grade in 2013 with regard to elementary computer education[3]. Individual countries are emphasizing the basics of computer science in consideration of their respective educational environment. Recently, information education is going through another change, i.e. the maker culture. Maker refers to a person who uses digital devices and various tools to realize his/her own idea[4]. As global interest in IoT and 3D printing technology as well as this maker culture is increasing, the environment is created in which anyone with an idea can easily make his/her own project[5]. In information education the learner must develop the ability to make, not use software. That is, SW makers, not SW players, must be fostered[6]. Maker education is emphasized. The programming course is also changing into a course for fostering

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makers. As part of the effort to reinforce maker education, the revised curriculum of 2015 made middle school information a mandatory subject, and physical computing was newly added. As interest in SW education is increasing in the US and the UK and programming education is being reinforced, discussion of physical computing has begun[2].

The purpose of the physical computing domain of the revised informatics curriculum is to design and develop programs for controlling the input, processing and operation of data using various sensors in order to solve problems in everyday life[7]. For this purpose of education, "functions" are proposed in terms of contents system. Function is the 'ability that a student can do or is expected to be able to do after class'.

It is very important in this study to analyze what function is and whether it is set up appropriately for the relevant domain. For all classes or curriculums can be expressed through functions. The purpose of this study is to review whether the physical computing function is properly configured, and how necessary the proposed function is.

2. Related Studies

2.1 Physical Computing

Physical computing refers to computing for physically receiving information from users using digital technology or physically outputting the result of information processing physical[8,9]. Education utilizing physical computing can create an interactive environment, and we can learn computer science and engineering knowledge[10]. In particular, physical computing, based on low costs, powerful performance and the open source culture, is growing fast thanks to the appearance of 'Arduino', open source hardware with broad communities and rich references[4].

Arduino, open source hardware (OSHW) developed in Italy in 2005, uses micro controllers. It is a small board that was developed so that students with no experience in embedded development can use it easily[11]. Researches using physical computing interact with other visual programs in real time to show visual effects[12], or use Arduino in VR (Virtual Reality), AR (Augmented Reality) and projection mapping to create works that provide storytelling[13]. In medicine, researches are being conducted to make animation therapy models[14] that can induce active participation through physical computing.

Information education is no exception. Physical computing was added to secondary education in the revised curriculum of 2015. Emphasis is placed on using physical computing to help students understand the operating principles of computing devices and using various sensors to design and develop programs. However, physical computing education has positive aspects, i.e. application of latest computing technologies and education methods, but researches on educational effects are still insufficient, and it is difficult to apply physical computing in reality[15].

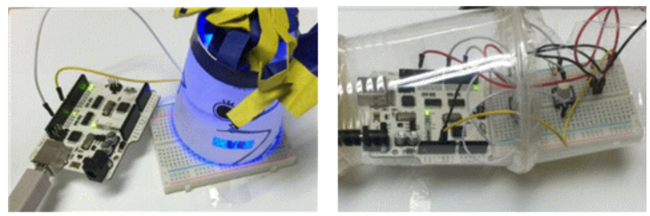

Figure 1. A student's work made with an Arduino board.

2.2 Functions in the Physical Computing Domain

The contents of the informatics curriculum are divided into 'information culture', 'data and information', 'problem-solving and programming' and 'computing system'. What follows is the contents system of the computing system domain that includes physical computing16. The core concepts of the 'computing system' domain are 'the operating principles of the computing system' and 'physical computing'. 'Physical computing' configures a physical computing system with micro controllers and various I/O devices, controls it through programming, and implements sensor-based programs and physical computing Table 1.

The 'functions', which were newly added in the revised informatics curriculum of 2015, are 'analyzing', 'designing', 'programming', 'implementing' and 'cooperating' in the middle school curriculum, and 'using', 'managing', 'designing', 'programming', 'implementing' and 'cooperating' in the high school curriculum. The items of the contents system including functions are defined as follows:

- Domain: It is the top-level curriculum content category that best represents the nature of the curriculum, and 'core concepts' are the basic concepts or principles of the curriculum.
- Generalized knowledge: universal knowledge that students must learn in the domain.

Table 1. Contents system of the computing system domain

Domain (core concept)		Generalized knowledge Middle school	Function	
			High school	
Computing system	Operating principles of the computing system	The computing system which organically combines various hardware and software components receives data input from the outside, efficiently processes it and outputs it.	Analyzing Designing Programming Implementing Cooperating	Using Managing Designing Programming Implementing Cooperating
	Physical computing	Configure the physical computing system with micro controllers and various I/O devices, and control it through programming.		

- Function: The ability that students can have or are expected to have after class. It includes the investigation process and thinking function unique to the curriculum.

3. Research Methodology

3.1 Research Procedure

In this study, the research procedure for analyzing the suitability of the functions proposed in the contents system of the physical computing domain, newly added to the revised curriculum of 2015, is as follows:

3.2 Composition of the Questionnaire

The survey of this study is configured as follows. First, we analyzed the definition of 'function', which was proposed in the revised curriculum, in the introduction. Second, we tried to check the suitability of 'function' in the physical computing domain of the revised informatics curriculum. Third, the survey was administered to informatics curriculum experts to verify the content validity. Fourth, we checked if any of the survey contents is difficult to understand, and we modified the survey accordingly. Fifth, we derived the final survey, and administered it to experts.

3.3 Subjects

The subjects of this study must sufficiently understand the informatics curriculum. Considering that they must understand the curriculum very well, we selected experts as subjects. The conditions for experts are as follows:

First, they must have at least 5 years of experience in teaching the informatics curriculum in schools.

Second, they must have at least a master's degree in relation to information education.

Third, they must have at least 3 years of experience in secondary education rather than elementary education.

Fourth, they must have at least 5 years of experience in researches related to information education.

Fifth, they must have experience in writing teaching materials related to information education.

Those experts who meet 3 or more of the above conditions were selected. Accordingly, 10 experts, including 4 teachers with a master's degree or higher, 3 researchers who have a master's degree or higher and experience in education-related researches, were selected as subjects.

3.4 Tools Used

The number of functions for each school level is 5 for middle schools and 6 for high schools. Considering the differences in the number and contents of functions, middle schools and high schools separately surveyed. Literature analysis and curriculum analysis were conducted for each of the functions proposed for each school level, and the contents of the survey were divided into 'suitability', 'importance' and 'necessity'. The contents of each survey domain are shown in Table 2.

Table 2. Contents of the survey

Classification	Description
Suitability	Is it suitable for the scope and concept of the learning objective?
Importance	How important is the function to the achievement standard after learning?
Necessity	Is the function proposed for the domain necessary for the learning process?

The 'suitability', 'importance' and 'necessity' of each function were measured with a 5-phase rating scale with the maximum score being 100 points.

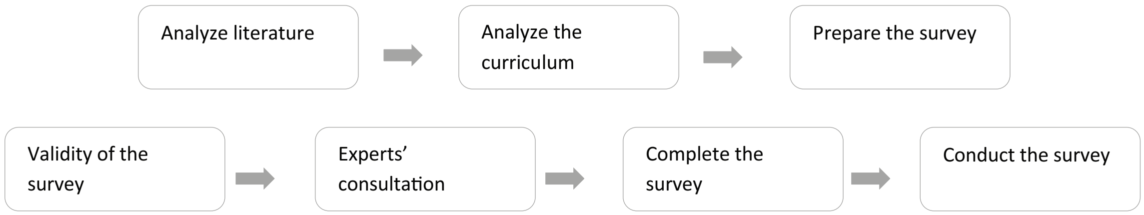

Figure 2. Research procedure.

4. Results

4.1 'Function' in the Middle School Informatics Curriculum

The opinions on the suitability, importance and necessity with regard to physical computing functions in the middle school curriculum were analyzed, and the analysis result is shown below Figure 3.

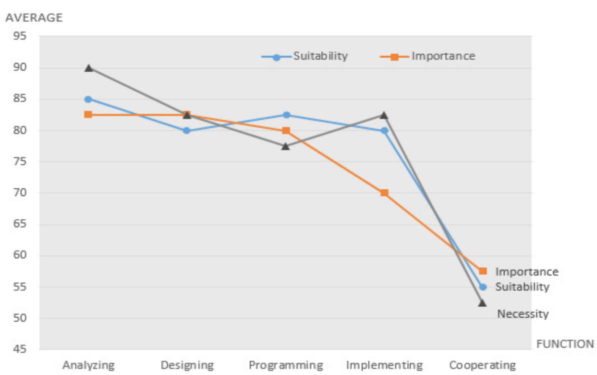

Figure 3. The item averages of the functions in the computing system domain of the middle school curriculum.

'Analyzing', which exists only in the middle school curriculum, had a higher level of suitability, importance and necessity than other functions. In general, 'designing' and 'programming' had a high level of suitability, importance and necessity as opinions about the appropriateness of suitability, importance and necessity were mixed. Analyzing, designing and programming can be said to be the basic functions of physical computing.

On the other hand, 'implementing' had a higher level of necessity and suitability than other functions, but a noticeably lower level of importance. Considering the objective of functions, i.e. 'fostering programming abilities and attitude for designing solutions to problems from the viewpoint of computer science and implementing them in software', we can have the following discussions. For starters, do two functions have the same meaning? If they are different functions, a specific standard for each function is necessary. We examined experts opinions about whether 'programming' and 'implementing' are the same functions. The view that the two functions are the same regarded them as identical from the viewpoint of 'deriving results' and 'programming and implementing in programming languages'. The view that the two functions are different emphasized 'programming' from the viewpoint of 'algorithm implementation and coding', in the limited sense of 'implementing the internal programs of physical computing', or from the viewpoint of 'writing programs to configure physical computing systems and control operations'. On the other hand, it emphasized 'implementing' from the viewpoint of 'the entire process of producing S/W as output so that information devices including H/W can be operated', in the limited sense of 'configuring physical computing to solve a certain problem and making it possible to control it with programs', or from the viewpoint of 'the process of executing developed programs and modifying and supplementing them' or 'programming all processes with the given contents'.

'Cooperating' showed the lowest levels in all items compared to other functions. Accordingly, there is a room for controversy as to whether it is suitable for the function, i.e. 'the ability that students can have or are expected to have after learning, including the investigation process and thinking function unique to the curriculum'.

4.2 'Functions' in the High School Informatics Curriculum

Opinions about the suitability, importance and necessity of physical computing functions of the high school curriculum were analyzed. 'Analyzing' of the middle school curriculum in the computing system domain of the high school curriculum was excluded, and 'using' and 'managing' were added. The analysis result showed that 'analyzing' was rated the highest in all domains in the middle school curriculum, but it was rated differently depending on domains in the high school curriculum. 'Programming' had the highest rating in importance, and 'implementing' was rated highest in suitability, 'Designing', 'programming' and 'implementing' were rated the same in necessity Figure 4.

In general, 'managing' was rated low, and the differences in ratings were much smaller in importance or necessity than in suitability. The low ratings of importance or necessity mean that S/W or H/W operations are viewed simply from the perspective of 'management'. It is necessary to further clarify the function related to 'managing' in physical computing.

'Cooperating' was rated low in all items as in the middle school curriculum. Accordingly, it is necessary to examine whether the cooperating function is suitable for achieving the learning objective. We examined experts' opinions on whether to view 'cooperating' as a function, or as a learning method. They said that it is a function 'capable of a new type of collaboration through computers, unique to the informatics curriculum', 'a function that is necessary and mandatory for all curriculums, not just the informatics curriculum', and particularly 'a function that is required more for physical computing that needs collaboration' and 'a function that is not an investigation process unique to the curriculum, but collaboration and communication'. On the other hand, There were negative views too, e.g. 'a method of programming rather than a function of collaboration' and 'it is not a function that can be expected after learning, but one of the learning methods, i.e. 'collaborating''.

4.3 'Revision of Bloom's Taxonomy of Educational Objectives' in Consideration of Functions

In education, learning objectives must be present so that they clearly show what students will learn[17]. To this end, the 6 levels of the cognitive process of Bloom's new taxonomy of educational objectives were compared with the 'functions' of physical computing Table 3.

This study considered only the roles of the functions of physical computing in learning without distinction between middle schools and high schools. The result showed that 'Remember' in the new taxonomy of educational objectives does not have a corresponding function, and 'creating' could be compared with managing and using. Meanwhile, cooperating of physical computing did not match any of the new educational objectives.

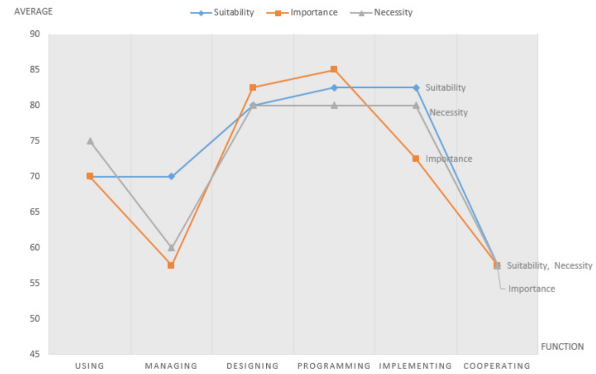

Figure 4. The item averages of the functions in the computing system domain of the high school curriculum

Table 3. Bloom's New Taxonomy and comparison of functions

Classification of the objectives of new education	'Functions' of physical computing
Remembering	
Understanding	designing
Applying	programming
Analyzing	analyzing
Evaluating	implementing
Creating	managing/ using

5. Conclusion

This study examined whether the functions of the physical computing domain, newly added to the revised informatics curriculum of 2015, are well organized through analysis of experts' opinions. The results of the research about the suitability, importance and necessity domain of each function are as follows:

First, 'analyzing' was rated highest in all domains. In the middle school curriculum, physical computing views the process of learning the basic concepts and principles of computer science as analysis. That is, the solution to a problem can be viewed as a function that must be provided before designing from the viewpoint of computer science.

Second, 'designing' and 'programming' showed similar scores in all domains in both the middle school curriculum and the high school curriculum. In the physical computing domain, the two functions can be regarded as the most basic and suitable functions.

Third, 'programming' and 'implementing'. Many experts viewed programming as the domain of implementing internal programs, and implementing as configuring the physical computing system. There must be a clear boundary line between the two functions.

Fourth, 'managing' had low scores in general, and the differences in the scores for importance and necessity are greater than that for suitability. 'Managing' in physical computing needs to be suggested as a function that high school students may expect after learning the above rather than managing in SW or HW domains.

Fifth, 'cooperating' had low scores in all items. Viewing collaboration from the viewpoint of 'sharing knowledge and information for problem-solving, efficient communication and improving collaboration capabilities', it can be seen as the role of the function. In the sense of 'cooperation', it can be viewed as one of the learning methods to achieve learning objectives. In experts' opinions, it was rated noticeably lower than other, which supports this argument.

Sixth, in comparison of Bloom's New Taxonomy with the functions of physical computing, 'remembering' did not have a corresponding function. On the other hand, 'cooperating' was not in Bloom's educational objectives. If the ability that students can have or are expected to have after class is 'function', the proposed functions need to be studied so that maker education through physical computing can be realized.

For curriculums to become meaningful education as they are conducted in a way fit to educational objectives, well-made educational designs are necessary. Physical computing, added to the revised curriculum, is education for maker education, and more appropriate educational designs are required. This study is meaningful in that it examined whether the functions proposed in physical computing are suitable as functions that can be expected in students after learning. It will be necessary to further investigate whether the functions are suitable for the objectives of information education that will be achieved through physical computing education in the field.

6. Acknowledgement

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