

## Design of the rubrics evaluation lists and the education contents for improve the computational thinking by using physical computing tool

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### Abstract

*The purpose of this study is to design education program and computational thinking (CT) rubrics evaluation lists using physical computing tools to improve effective CT skills. To do this, we analyzed the elements of CT, rubrics evaluation lists, and physical computing tools, and presented 12 rubric evaluation lists for learners. The contents of the education program were designed based on the real-life problem solving (RPLS) model. The education program design set a one topic for artifacts to be consistent with are CT element. Based on the rubrics of Kim JK, designed by analyzing the CT framework, we devised a CT rubrics evaluation list used the physical computing tools. After, this study is expected to be used as an effective CT teach program using the physical computing tools through the verification of the empirical results.*

### Keywords

*Computational thinking, Physical computing, Rubrics, CT-RLPS.*

### 1.Introduction

Starting from the science technology engineering mathematics (STEM) education from the national science foundation in USA. Arts added, STEAM education has become a major educational goal of each country. STEAM education means a convergence education for educating talented students. Therefore, as the fourth industrial revolution of industry approaches, the world is hastening to prepare about STEAM education. Currently, computer software (SW) education is emphasized as a stem of STEAM education. The reason is that SW education itself is associated with the fostering of convergence talents required by STEAM. In 2006 Wing JM, presented the concept of computational thinking (CT) [1]. It is not like training of computer science engineer, people should have logical and analytical thinking skills like the computer scientists. In the fourth revolution of industry, the ability to read and interpret digital media and produce new digital contents is the basic skill of a new social member [2].

In this context, SW education can get various educational effects by learning problem-solving ability, logic, structuralization, and computer literacy that is the basis of future SW technology.

For this reason, K-12, a regular education program in the United States, is making computer science education compulsory and programming education was compulsory in the Denmark, Australia and France [3]. In the republic of Korea, the revised information & computer education course was announced in 2015 and the information & computer curriculum for middle schools was compulsory in 2018. However, it is not easy to evaluate the abstractedness because CT education which is the main purpose of the SW education is the thinking skills. Therefore, research on CT learning is actively being carried out in order to present the direction of SW education evaluation. Current research on CT evaluated was being developed focused on the use of scratch, an educational programming language. There are not many CT education research on physical computing tools that enhance student interest and learning effectiveness. The reason of difficulty to design of teaching methods in detail for CT on physical computing is that it has the widest range of

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physical computing tools and the definition of physical computing tools for CT education is unclear. In CT education, it is generally forced on Arduino, one of the educational tools of physical computing tools. Therefore, for the improving the effectiveness of SW education, CT education program using physical computing tools based on CT training model and framework is needed. This research is analyzed using physical computing tools to make effective education for CT ability improvement. And plan to design a CT training program using physical computing tools based on the CT rubric evaluation list and CT education model. Therefore, in order to enhance the effectiveness of SW education, CT education program using physical computing tools based on the CT framework teaching model is needed. The purpose of this study is to analyze the physical computing tools and CT elements for effective to improve CT competence.

For this purpose, it is based on both the rubrics list and selected CT education models. We plan to design a CT education program used physical computing tools. In this study, we analyzed the CT element and rubric evaluation in the following order. First, the CT elements are analyzed and defined. Second, we select a physical computing tools suitable for CT education. Third, analyze rubrics evaluation lists for CT education. Fourth, we will design new rubrics evaluation lists using physical computing tools by applying physical computing tools and rubrics evaluation lists. Fifth, we will design to the CT education program based on new CT rubric evaluation.

**2.Theoretical background**

**2.1CT elements and rubrics evaluation**

About CT elements, Brennan and Resnick [4] have developed a CT evaluation framework as shown in *Table 1*.

**Table 1** CT framework of Brennan and Resnick

<b>Computational concepts</b>	<b>Computational practices</b>	<b>Computational perspectives</b>
<ul style="list-style-type: none"> <li>•Sequences</li> <li>•Loops</li> <li>•Parallelism</li> <li>•Events</li> <li>•Algorithms &amp; procedures</li> <li>•Conditionals</li> <li>•Operators</li> <li>•Data</li> </ul>	<ul style="list-style-type: none"> <li>•Being incremental and iterative</li> <li>•Testing and debugging</li> <li>•Reusing and remixing</li> <li>•Abstracting and modularizing</li> </ul>	<ul style="list-style-type: none"> <li>•Expressing</li> <li>•Connecting</li> <li>•Questioning</li> </ul>

Bort & Brylow [5] presented a Rubric for measuring CT. The ten basic CT elements of the Computer Science Teachers Association (CSTA) presented in *Table 2* were evaluated on three scales. CSTA of the United States, International Society for Technology in Education (ISTE), and the College Board (CB) and

National Science Foundation (NSF) are presented: detailed components of CT follow. In CSTA & ISTE, 10 CT elements were divided into three stages and evaluated.

**Table 2** Elements of CT

<b>CSTA &amp; ISTE</b>	
<ul style="list-style-type: none"> <li>•Data collection</li> <li>•Data analysis</li> <li>•Data representation</li> <li>•Problem decomposition</li> <li>•Abstractions</li> </ul>	<ul style="list-style-type: none"> <li>•Automation</li> <li>•Algorithm &amp; procedures</li> <li>•Simulation</li> <li>•Paralleization</li> <li>•Connection to order fields</li> </ul>
<b>CB &amp; NSF</b>	
<ul style="list-style-type: none"> <li>•Connecting computer</li> <li>•Creating computer</li> <li>•Artifacts</li> <li>•Abstractions</li> </ul>	<ul style="list-style-type: none"> <li>•Analyzing problems and artifacts</li> <li>•Communicating</li> <li>•Collaborating</li> </ul>
<b>Selby &amp; Wollard</b>	
<ul style="list-style-type: none"> <li>•Algorithmic thinking</li> <li>•Decomposition</li> </ul>	<ul style="list-style-type: none"> <li>•Generalization</li> <li>•Abstractions</li> <li>•Evaluation</li> </ul>

Then in 2017, Kim JK, based on the learning objectives of computational thinking practices in the AP computer science principles curriculum framework of CB. He proposed improved rubric evaluations through abstraction and configuration classification of artifacts [6].

As a result of the research about *Table 3*, it was confirmed that we obtained the ability to solve the computing problem through the proposed Rubric evaluation item. In this research, learners showed errors in data conversion in *Table 3* P1. The conversion of a data type from a computer differs

from the unit that the computer handles according that we routine to the integers and decimal fraction. It is a common error of a novice programmer.

We confirmed that there is an error in the final output, in the process of integrating and verifying the modules in the collaborative process of *Table 3* P4. This is because the names of variables and functions used by learners are different from the integrated part of the result. It is necessary to supplement the theoretical lessons to the integration of the outputs and testing.

**Table 3** Kim JK (2017), proposed rubrics evaluation lists

CT	Category	Sign	Rubric evaluation lists about CT
Abstracting	Connecting computer	P1	1.Understanding data representation and transform encoding techniques 2.Abstract logical symbol semantics and real-world logic representation 3.Understand the types, principles, and necessities of data structures and operations
	Analyzing problems and artifacts	P2	1.Understanding the types and functions of control flow commands 2.Divide and represent problems and define and modularize modules 3.Identify the patterns, logic and skills needed to solve the problem
	Communicating	P3	1.Understanding abstract symbols to express problem-solving process
	Collaborating	P4	1.Reduce troubleshooting costs for parallel processing and collaboration
Artifacts (Automation)	Connecting computer	P1	1.Valid constants and types according to data type 2.Use Boolean expressions with valid logic and syntax 3.List and dictionary definition, operation
	Creating computer artifacts	P2	1.Control flow using condition and loop 2.Modular programming using functions and arguments 3.Creating arithmetic, logic, comparison and regular expressions
	Communicating	P3	1.Reflection of modeling code for problem solving of abstract code
	Collaborating	P4	Module creation and integration testing through collaboration

In addition, structural programming is not smoothly implemented in the modularization part through function definition. These errors can be suggested improved by supplementing teaching and learning methods. Therefore, we made additional chapters on simulation and collaboration.

Using the cronbach's alpha coefficient, J.K. Kim tested reliability was verified in 0.73 and Abstracting for artifacts and 0.8.

**2.2 Concept of physical computing**

Physical computing, Prof. Dan O 'Sullivan and Prof. Tom Igoe, taught Interactive physical systems in the interactive telecommunications program, a graduate program at New York University, and categorized the technical forms of physical computing into four categories [7].

Physical computing expresses that inputting information in a way that senses physical signals such as sound, motion, light, heat and etc. instead of input methods such as a keyboard or a mouse. To do this, physical computing uses a microcontroller to control the digital input, the digital output, the analog input, and the analog output. When any physical input is received from the user, it outputs the result to the user in digital or analog method. Physical computing has the advantage of being able to access digital media in a variety of ways, even for those unfamiliar with computers.

**2.3 Education model for CT education**

Seiter & Foreman's progression of early computational thinking (PACT) model is often used in domestic evaluation studies. The learner's scratch output was evaluated as evidence variables, design

pattern variable and computational thinking concepts [8].

In 2016, Sung YH, presented a CT-SPI model to improve the computing thinking ability. To internalize using an Arduino to learner internalize the CT element constructing construct the system thinking, prototyping, and interaction order [9].

In 2017, Lee CH, has developed the computational thinking-based real-life problem solving (CT-RLPS) model for software education [10]. The CT-RLPS model consists of three stages: problem analysis and decomposition, design and implementation. His research is to educate computing thinking by applying sub-elements of each step to real life problems. The contents are shown in *Figure 1*. In this paper, CT education curriculum that uses physical computing tools, based on CT-RLPS, was designed.

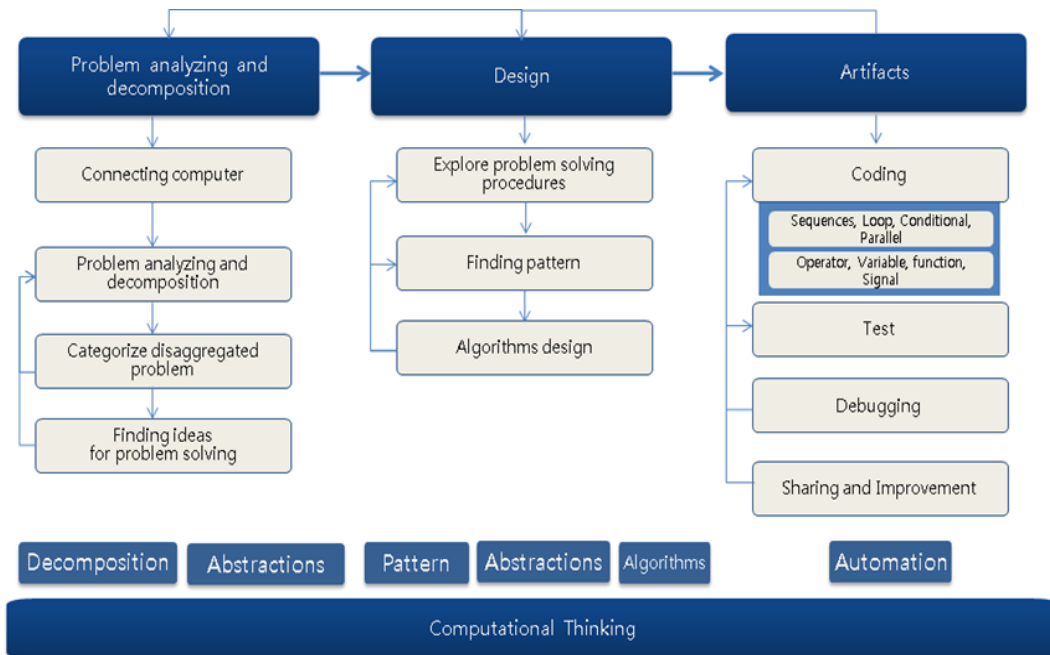


Figure 1 CT-RLPS model

### 3. Contents

#### 3.1. ICT education elements elicitation: based on rubric evaluation lists uses physical computing tools, for improving CT

For CT education improvement, it is necessary to summarize abstract concepts and express them in physical computing tools to solve problems. The contents are as follows, which is based on the Brennan & Resnick framework for CT evaluation using physical computing. Then we applied the rubrics suggested elements of Kim JK to reconstruct the existing CT element and set the CT element. The rubrics lists designed were reviewed by three experts. The final rubric was determined through a questionnaire.

1. Must be expressed in the physical computing tools after analyzing in the real world of abstract data.
2. It must be available tools of transforming and expressing data types.

3. To solve the problem, it should be able to understand and written the abstract concept through the tools.
4. For the purpose of parallel processing, it should be able to understand and express the concept of shortening the cost of problem solving, through parallelization in the tools.

Also, for CT enhancement training, the physical computing tools should be able to implement the automatic resolution of the problem and be capable of logical and iterative sequential configuration.

1. Transformation between data and data error correction according to the format of data must be expressed or understandable.
2. Apply correct logic and grammar usage so that the results can be verified in the tools.
3. Should be able to see the results of the operation, according to the data structure using lists, definitions, and operations.

4. Should be able to express the flow of control by using conditions and loops.
5. Should be possible to express and implement modularization using functions.
6. The solution of the problem should be able to be understood or expressed by the code writing flow and commands, and the modular expression should be possible by dividing the problem. Functions related to problem solving should be able to be expressed in logical order.
7. Automated module and logic, grammar must be running concurrently in parallel.

### 3.2 Select of physical computing tool for CT improving





Arduino, one of the representatives, physical computing tools used in CT education is actively used in CT education because of its advantage that it can be easily programmed without electric and electronic expert knowledge.

However, it has a disadvantage that CT learners take more time in Arduino circuit design and assembly than actual CT learning. Therefore, in order to be effective CT education using physical computing tools, there are studies on diverse physical computing tools. And because of this reason's various companies are developing and education selling tools for CT education. *Table 4* shows the physical computing tools based on the Arduino. Corp. Makeblock's m-bot simplifies circuit and wire connections, made in China. The sensor board of the ENTRY education center, which was created for education by adding input/output sensors mainly used in CT training, made in Korea. Based on Arduino, integrated hardware platform named coconut equipped the input and output devices and motors, made by corp. Huintech in Korea.

Based on the Arduino, each company added essential functions to make it easier for learners to learn CT, added circuitry and Bluetooth capabilities so that the learners did not spend unnecessary time on circuit design and data upload / download.

Organizing CT education program using coconut from corp. Huintech which is a robot-type tool with a motor to facilitate instant expression and understanding of modularization and parallelization, which is one of the components of CT.

**Table 4** Physical computing tools-based arduino for CT teaching

	Arduino	M-bot
image		
	Sensor Board	Coconut
image		

A number of similar physical computing tools have been developed. In a typical computer environment, simple software installation enables immediate CT training. Applications corresponding to tablets or smartphones are also provided. Therefore, learners can make CT learning more interesting, fun and easy.

### 4. Result

The following CT-RPLS model education program was proposed based on the rubric evaluation items based on the CT education elements. The CT curriculum of the activities, education curriculum and the activities, education contents of the secondary information curriculum are composed of simpler sorting tasks and corresponding CT elements among them. There is a need to provide an organic and systematic context flow between the electronics prototyping lab (EPL), the physical computing paradigm, and the algorithm design used for CT learning. The CT components of CSTA & ISTE are organically thought out for the problems to be solved: data collection, data analysis, data representation, problem decomposition, abstraction, algorithms and procedures, automation, simulation and parallelization. In order to improve the CT, the physical computing utilization education program design is shown in *Table 5*. The education design should be conducted on a 12-week basis for two hours a week. Do not perform separate artifacts for each chapter. In order to produce one security robot, we have taught for 12 weeks. Each step has an organic relevance for the final output, and finally, each stage feedback is possible and CT learning can be achieved by completing integrated education.

The CT framework of Brennan & Resnick presents the conceptual domain of CT and Kim JK proposed rubrics evaluation lists presented the rubric evaluation direction of CT. CT education is a convergent model of education, where problem solving and disassembling, design and abstraction, automation and implementation are linked to each

other. The education must be made with connectivity and continuity between CT elements. Therefore, a training program and rubrics evaluation linked to integrated flow using direct the physical computing tool for the CT improves based on the CT-RPLS model is shown in *Table 6*.

**Table 5** Physical computing education program for CT improving

Chapter	Contents	CT Elements	CT-RLPS
1	Basic	Physical computing and CT basic	-
2	Connecting computer	Development of security robot	Data collection
3	Data analysis	Understand differences in representation by data type	Data analysis
4	Problem decomposition	Problem resolution 1. Obstacle detection 2. LED 3 Sound	Problem decomposition
5	Problems abstractions	Configure action for problems solving	Abstractions
6	Expressing of data	LED change according to sound	Data presentation
7	Problems parallelization	Parallel configure action for problems solving	Parallelization
8	Problems solving sequences	lists and sequence structures creating	Algorithms& procedures
9	Conditionals and loops control	Operation set when obstacle is detected	Algorithms & procedures
10	Functions and modularization	Security robot action function creation and modularization	Automation
11	Artifacts test	Determine the logic of abstraction is correctly represented.	Simulation
12	Creating an integration module	Each function are operated parallel action	Parallelization simulation

**Table 6** Evaluation rubric items for CT: used physical computing tools

	Evaluation list
1	Basic
2	Connecting computer
3	Data analysis
4	Problem decomposition
5	Problems abstractions
6	Expressing of data
7	Problems parallelization
8	Problems solving sequences
9	Conditionals and loops control
10	Functions and modularization
11	Artifacts test
12	Creating an integration module



## 5. Conclusion

Following this paper to explore rubrics evaluation items for CT improvement based on the CT elements and CT framework. Through the CT-RLPS model CT education program which has used physical computing tool was suggested. This will allow CT learners to learn the components of CT and logical thinking systematically. The rubric evaluation lists and the educate design were designed for effective SW coding teach and CT learner. This paper has limitations that must be applied and verified in actual schools. However, CT training should not be limited to the artifacts of irrelevant of CT learning and the acquisition of basic programming skills. I hope that it will help me to acquire more sophisticated and gradual CT skills.

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## Conflicts of interest

The authors have no conflicts of interest to declare.

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