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Review Article

A Study on the Functionality and Effectiveness of SW Education Tools

Pyung Kim

Dept. of Computer Education, Jeonju National University of Education, 50 Seohak-ro, Wonsan-gu, Jeonju-si, Jeonbuk, Korea

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Abstract *- SW education is an education for cultivating talented individuals who solve problems logically through computational thinking and is operated as a regular school curriculum in the elementary, middle and high school education environment since 2019 in Korea. Educational programming languages use languages for block programming, text programming and app programming. Education is carried out using the SW education tools such as the unplugged education, robot and sensor board, Arduino, and drone. This paper is to analyze the current status of educational programming languages and education tools utilized in the elementary, middle and high school SW education curriculum and to analyze the functionality and effectiveness of educational programming languages and education tools in the SW education curriculum so that it can help in selecting the educational programming languages and education tools in the elementary, middle and high school SW education and utilizing in the education curriculum design for prospective teachers.*

Keywords *- SW Education, Educational Programming Language, SW Education Strategy, SW Education Tools.*

I. INTRODUCTION

The SW revolution is in the centre of paradigm change into the 4th industrial revolution. The development of SW technology such as artificial intelligence became a critical factor that accelerates technology development and industry change. In particular, the fast-developing high-tech SW technology is undergoing substantial changes throughout the entire industry and society under the name of the 4th industrial revolution, and the SW education that conveys SW capabilities is becoming required, not an option to people who will live the hyper-connected and super-fusion era [1]. The goal of SW programming education, which is the core content of the "information" curriculum, is to cultivate the integrated and creative people of talent to strengthen their capabilities to solve the problem in various studies and industries through computational thinking.

Computational thinking makes it easy not only to collect and analyze the data but also to solve various problems simultaneously by parallelizing problems. In other words, if issues of different fields in everyday life are computerized to solve with a computer, this will be made easy to apply to other problems with similar types, as well as to find more effective and accurate solutions.

Many countries, including the United States, United Kingdom, Japan, China, Israel and Finland, operate computer education as a required curriculum. The SW centred "information" subject became a required course in Korea through the 2015 revised curriculum. After SW education became a requirement in the middle school in 2018 and the elementary school in 2019, the elementary and middle schools are trying to invigorate SW education through regular curriculum, after school activity or club activity. A variety of educational programming languages (EPL) are used for SW education, and SW education tools with various functions are developed and utilized to enhance the effectiveness of SW education.

EPL, a programming language developed as an instrument for programming learning, has been designed and developed for programming education rather than a professional program development tool for real problem-solving. Initially, the programming languages emerged to lower the entry barrier of professional education in general-purpose programming languages (C, Java, etc.). However, they are getting a spotlight these days as a learning tool to enhance logical/procedural thinking through training of making and programming algorithms rather than developing the actual application. Since education tools such as board, robot, sensor board, Arduino and drone help solve the problems and improve logical thinking according to various external stimuli, they are actively utilized in SW education.

With the invigoration of SW education, various forms of EPL and SW education tools have been variously developed and utilized. Still, the systematic analysis on the functionality and effectiveness of EPL and SW education tools are not good enough yet. This study is to help select EPL and education tools suitable for step-by-step SW education by analyzing the functionality and effectiveness of EPL and education tools utilized in SW education.

In this paper, Chapter 2 describes the directions of SW education in foreign countries, cases in SW education and the selection criteria for SW education tools on existing studies, Chapter 3 analyzes the functionality and effectiveness focused on EPL and SW education tools, and Chapter 4 describes the conclusion.

II. RELATED STUDIES

The content of the elementary information curriculum can be divided into areas of "information culture", "problem-solving and programming", and "computing system" [2], and recently, classification by size for computer science is gradually expanding in major foreign countries. The interdisciplinary integration tends to be invigorated. As shown in Table 1, China, the United Kingdom and EU countries exert every effort on AI education, and Japan is planning for artificial intelligence education throughout elementary, middle and high schools [3].

Table 1. SW Education Direction in Foreign Countries

Country	SW Education
United States	- Promote STEM + computing education with the aim of convergence focused on technical and engineering design - Focus on the latest computer science technology and artificial intelligence education
United Kingdom	- Adapted as a compulsory curriculum in elementary and secondary schools and proceed the coding and programming education in all stages of education from 5 to 16 years old. - Focus on computer science, IT technology, digital skills
EU	- France: Since September 2016, reduce the time for humanities, language and literature subjects and include the 'computer science and programming (ISN)' in the collèges curriculum as a regular subject - Finland: Try to include the programming in the curriculum as a STEAM educational tool - Estonia: Enhance the programming and robot education led by HITSA organization - Poland: Operate the information education in elementary education and computer science in secondary education as a regular subject
China	- Develop the repetitive and in-depth AI curriculum connecting from kindergarten to elementary, middle, high school and vocational school - In elementary school, focus on algorithmic thinking, and in secondary school, focus on the programming and AI utilization and production
Japan	- Implement programming and AI education in all elementary schools from 2020 - From 2022, designate "Information I" as a required subject in high school, focus on application and primary subject in the college entrance exam, and connect to the continuing education

A Model Curriculum for K-12 Computer Science in 2017 presented by 2017 CSTA (Computer Science Teachers Association) mentioned artificial intelligence for 11 to 12th grades. Korea plans to introduce artificial intelligence in the elementary, middle and high school curriculum driven by the ministry of education [4].

The educational programming language is developed to be used to enhance the learning of general programming language or logical and procedural thinking. Therefore, it has the following characteristics [5].

- A language designed for logical programming education rather than professionally developed language for real problem solving
- A language suitable for improving the logical and procedural thinking through the training of designing and programming the basic algorithm
- A language that is simple in grammar for beginners to be used efficiently and can acquire easily through the intuitive interface
- A language that is easily able to transfer to another programming language
- A language that is possible to link with various educational tools and to have free expression, application and extension

For computational thinking in SW education, the following four critical thinking abilities are necessary: First, decomposition is breaking down the large and complex problem or structure into smaller parts. Second, pattern recognition is looking for the similarities inside each broken piece or between damaged parts. Abstraction is only concentrating on the critical information and ignoring the related details. Algorithmic thinking is developing the step-by-step solution or rules that must follow to solve the problem [6].

When looking at the SW education status and education cases of the elementary and secondary courses, it can be divided into four activities, including activity that looks for algorithms in daily life, unplugged activity, block type programming activity and tangible programming activity.

- Algorithm: Education on concepts of procedure, selection and repetition for daily life
- Unplugged activity: Education to help understanding of operation principle of computer and algorithm through activities such as board or play
- Block style programming: Programming education using Code.org, Entry, Scratch and Kodu

- Tangible programming: Makers education for problem-solving in daily life using sensor board or robot

SW education tools used in the unplugged or tangible programming activity have higher educational effectiveness because it is possible to have immediate feedback for results through learner's manipulative activity, unlike the existing programming learning and can improve the learning interests and satisfaction of the learners. For selecting the physical computing education tools, safety and durability, compatibility on subjects and curriculum, relevance to developmental stages, multifunction, manageable control and trustable quality, relevance to the curriculum, economic efficiency and service of the educational tools have to be considered [9].

- Safety and Durability: Does it have the risk of safety accidents, contain hazardous substances and what is the robustness of the product
- Compatibility on subjects and curriculum: Can it be used for various issues and curriculum
- Relevance to developmental stages: Is it suitable for use by students in elementary and secondary school
- Multifunction: Is it possible to link with various sensors or EPL and to extend the function
- Easy control and Trustable quality: Is it easy to use in learning and education and to produce the reliable results
- Economic efficiency: Economic feasibility considering the budget scale of elementary and secondary schools

III. EPL AND SW EDUCATION TOOLS

After presenting the SW programming stage for elementary and secondary education, the functionality and usability of educational tools used in the school academic field were analyzed, centred around the EPL and SW teaching aids.

A. SW Programming Education Stages

SW education in the elementary and secondary courses must progress through basic computer theory and programming, so like Fig. 1, it is preferred to progress sequentially in the steps: understanding the computer, understanding SW coding, unplugged computing, block programming, text programming, then AI programming.

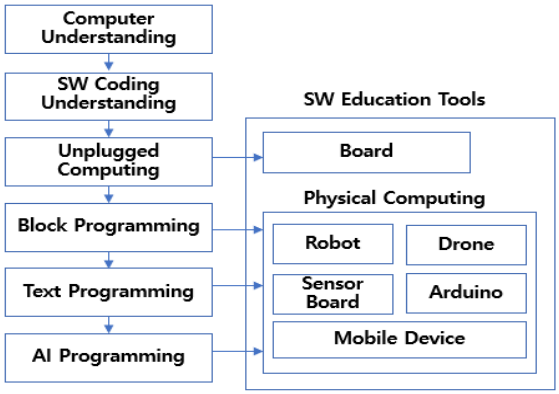

Fig. 1 Stages of SW Programming Education

AI programming is included in the SW education stage due to the recent increase in the importance of AI education and the planned introduction of an AI curriculum within a few years. It is possible to increase educational effectiveness by using SW educational tools at each step to teach SW, and SW education tools can be classified into usable boards at the unplugged activity step, physical computing tools including functional robots, drones, sensor board and Arduino at the programming stage.

B. EPL

The priority in SW programming education at the elementary and secondary level should not be completing programs but rather creative thinking for various problems and programming experience. In addition, multiple education contents and classes can be constructed for the same languages, including concepts on the programming command and structure, utilization of data structure and the complexity analysis according to the algorithm. If the programming education does not match the learners' level, it can cause the learner to feel antipathy, so rather than which EPL is selected, it is essential to set the learning scope to meet the educational objectives.

As shown in Table 2, EPL was classified as the web-based education service, block programming, transition from block programming to text programming, text programming linked to GUI, game programming, and app programming, and their characteristics were described. As indexes to determine the functionality and effectiveness of EPL, ease of use, role as an education platform, completeness of education program, interest in the service, expandability, physical computing connectivity, and provision of education contents should be considered.

Table 2. Types and characteristics of EPL

Category	Contents and Services
[Web] - Code.org	- Provides real-time coding and tutoring with a tutorial method for various languages (Java, PHP, Python, etc.) - Provides SW educational videos
[Block Programming] - Entry - Scratch	- Provides block style programming development environment appropriate for elementary and secondary education - Provides various physical computing connection environments - Provides development environment through sharing one's project and reusing
[Block to Text Programming] - Entry Python - Blockly	- Provides a function to change block programming results to text coding - Help in the process of changing block programming to text programming

[GUI- Text Programming] - Logo - NetLogo - Kojo - Alice	- Educational programming language of the GUI supported text programming method - Able to develop problem-solving and simulation programming through various functions, libraries and scripts
[Game Programming] - Kodu - Minecraft - Blockly Games	- Provides a function to teach event and logical techniques through game programming - Able to develop exciting games through character and event centred programming
[App Programming] - App Inventor - M-biz make	- Provides a simulation development environment for GUI-based apps - Able to develop GUI interface and sensor-associated app program

Understanding or procedural thinking of basic programming can be learned through Code.org, and the basic computer algorithm for problem-solving and information theory can be known through CS Unplugged education. Scratch has excellent program completeness as a block programming language, but in terms of the connectivity with education contents, education platform function and physical computing connectivity, Entry is better. In Entry Python and Blockly, which support the transition from block programming to text programming, since Entry Python has a characteristic of Entry, Kodu which can provide programming education through game production and Blockly Games that support the game production through block programming are easier to use than Minecraft. However, Minecraft is excellent in providing educational content and interest. For app development tools, App Inventor is better in ease of use since it is similar to Scratch, but M-biz makes in terms of educational content connectivity and expandability.

To prioritize EPL languages that are easy to learn but belong to the same category, based on the indexes to determine the functionality and effectiveness, it will be Web (Code.org) > Block Programming (Entry > Scratch) > Game Programming (Kodu > Blockly Games > MineCraft) > Block to Text Programming (Entry Python > Blockly) > App Programming (App Inventor > M-bizMaker) > GUI-Text Programming (Alice > Logo = NetLogo = Kojo).

C. SW Education Tool

Various SW education tools were developed and utilized for unplugged activity, including computer and physical computing education. Among SW education tools, the board is used to understand the primary computer and educate the algorithm without using a computer in the unplugged activity.

Table 3. SW Education tools

Category	Count	Tools
Unplugged Computing Board	15	Cento, Code Pang, Delicious Coding, Code Racer, Catch the Cat, Cubetto, Code Master, Run Coding Bus, Agent 12, Sixteen, Go & Stop, Zip, Binary, Signal, Scottie Go!
Complete Robot	14	Turtle Robot, Ozobot, Beebot, Hamster, DASH, True True, Robot Mouse, Kamibot, Coconut, Albert, Aquila, Kubo, Cubimon, Asome Kit
Prefabricated Robot	6	EV3, Wedo, MakeBlock, Cuboid, EQduino, COBL
Sensor Board	10	E Sensor Board, bitMusic, BitBrick, BitBlock, Makey Makey, LittleBits, Chocopi Board, micro: bit, iPOPCON, Davinci
Arduino	6	Genius Kit, Spark Fun, Orange Board, Brick Board, CODEino, CodingArray
Drone	8	DJI Tello, CoDrone, Petrone, AirBlock, MDS Kit, Zerone, FirmTech Drone, Arwood
Other	3	3D Printer, Drawing Pen Kit, Raspberry Pi

Since education tools that support physical computing can solve problems through the interaction with the natural world using sensors and actuators by extending to computer's input and output devices, they have contributed to the problem solving and improvement of logical thinking according to various external stimuli. In this study, 62 kinds of SW education tools utilized in SW education at schools were divided into a board, robot (complete or prefabricated), sensor board, Arduino, drone and others, as shown in Table 3.

Indexes to determine the functionality and effectiveness of SW education tools, ease of use, convenience and reliability of operation, functionality, interest in the service, expandability, simplicity of programming method, and price economy should be considered.

Boards used in unplugged activity consist of boards to help understand specific algorithms such as binary, image expression or alignment. They are used in education to understand computers and algorithms without using computers through the participation of students. Boards are low in price and limited in functionality. Still, they are easy to use and convenient to operate, so they have higher effectiveness in SW education through student activities in an environment without using computers. Robots can be divided into complete and prefabricated robots and are most widely used in physical computing education. Robots are moving through ELP or dedicated programs equipped

with sensors or actuators, or robots are programmed to recognize cards specified with movements. The completed robot is easy to use and manage, but it is difficult to change the shape.

On the other hand, the prefabricated robot can be assembled in various forms but is somewhat inconvenient to manipulate and manage. However, the prefabricated robot has multiple functions. It excels in the interest of use, expandability and simplicity of programming methods, but its price economy is low since its price is relatively high.

The sensor board is used in setting various environments and solving problems in Makers education, which is an activity that recognizes the values through ELP or a dedicated program and can perform the specified movement. Its convenience to use and operate is relatively low, but its expandability and price economy are better. On the other hand, Arduino, which is widely used in secondary education, can have signal processing using network or Bluetooth and is higher in its functionality that can work alone, expandability and reliability but its convenience to use and operate are low. Drones are more elevated in the interest of use. Still, for drones used in current SW education, their effectiveness is not high since actions that can be used through programming are limited. However, drones with motion control functions through visual recognition have been developed recently, the functionality and interest of use are getting higher. In addition to them, other education tools, including 3D Printer used in Makers education, Drawing Pen Kit and Raspberry Pi, are used in SW education.

IV. CONCLUSION

SW education is to understand the basic principle and concept of software and to develop the ability to think to solve various problems logically and creatively. In elementary courses, SW education should teach basic concepts of programming and logical ways of thinking through experience and play. In secondary classes, SW education should teach how to define the problem focusing on real-life issues, deepen understanding of basic concepts and principles of SW in the process of breaking up the problem step-by-step and connecting, and solve the problem creatively and effectively by clicking various areas and other subjects and studies.

With the invigoration of SW education, various forms of EPL and education tools have been variously developed and utilized as physical computing education tools. Still, the systematic analysis on the functionality and effectiveness of education tools are not good enough yet. This study suggested the steps for programming education and the basic computer theory for SW education in the elementary and secondary courses, indexes for determining the functionality and effectiveness after classifying EPL and SW education tools used for programming education in the elementary and secondary classes and described their characteristics. For EPL, ease of use, role as an education platform, completeness of education program, the interest of use, expandability, physical computing connectivity, and provision of education contents should be considered, and for SW education tools, ease of use, convenience and reliability of operation, functionality, the interest of use, expandability, simplicity of programming method and price economy should be considered.

Results of this study can be used to design the SW programming education courses to select SW education tools in the elementary and secondary classes and develop the plan for SW development ability and linkage with curriculum education for prospective teachers.

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