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Original Article

Functional Analysis of Educational Tools for Elementary School AI Education

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Abstract - *As future industries and educational paradigm changes are led by major technologies of the 4th industrial revolution, such as robots, AI, and IoT, talent cultivation through AI education in elementary, middle and high schools is becoming increasingly important. AI education is being strengthened in elementary courses in Korea, China, and Japan, as well as in the United States and the United Kingdom. Various research has been conducted actively to establish curriculums, human resource development, and educational infrastructure for AI education. In this study, we proposed a 7-step curriculum and major activities for elementary AI education through the analysis of the operation status of AI-leading school programs conducted since 2020 and the functions of SW and tools used for education. We focused on helping elementary school students to understand and utilize AI education more systematically by proposing educational tools that can be used for activities and actions at each step.*

Keywords - *AI education, elementary AI education, AI curriculum for children, educational AI program, educational AI tool.*

1. Introduction

Future industries and educational paradigm changes are being driven by major technologies of the 4th industrial revolution, such as robots, AI, IoT, etc.; interest in SW-related industries and future digital talent development is increasing. SW education is positioned as an essential competency for citizens living in the hyper-connectivity and hyper-convergence era. Therefore, SW education aims to nurture convergent and creative talents for strengthening the capabilities to solve problems through computational thinking in various academic and industrial fields [1,2,3].

AI education policies are being actively promoted in elementary and middle school courses in many countries, including China, Japan, the United States, the United Kingdom, and India [4]. China is most strongly promoting national AI education policies as entering the intelligent information era. Starting with the 'Next Generation Artificial Intelligence Development Plan' in 2017, China announced and implemented strengthened and advanced AI education policies yearly [5,6]. Japan is operating a system that promotes the employment of those who have completed level-based education and separate programs to nurture AI talent. In Japan, mathematics, data science and AI are included in the curriculums so that basic knowledge necessary for the intelligent information society can be acquired in elementary, middle, and high schools [7,8]. Starting in 2018, the US planned AI4K12 (AI for K-12 initiative) as a solution to strengthen computer science classes and expand AI. We developed five key learning topics called Big Ideas (recognition, expression and reasoning, learning, natural interaction, and social impact) to consistently link to the educational contents of each AI course of K-12 [26]. Korea has strengthened SW coding education since the revised curriculum in 2015. The revised curriculum in 2022 proposes expanding the number of hours for information education on data science, including computational thinking, AI education, AI ethics, AI mathematics, etc. According to the 2022 revised curriculum, which will be applied since 2025, a plan was announced to double the number of information class hours from 17 to 34 hours for elementary schools and 34 to 68 hours for middle schools [4,10].

This study proposes a plan to utilize AI educational tools more efficiently by analysing educational activities and the functions of the educational tools used in AI-leading elementary schools. Chapter 2 of this study reviews previous studies related to AI curriculum, leading AI education schools and educational tools, and Chapter 3 describes current educational programs of AI-leading schools. Chapter 4 analyzes the functions of elementary AI educational tools and proposes activities, and Chapter 5 concludes.

2. Related Studies

Korea designated 247 AI-leading schools in 2020, 566 schools in 2021, and 1,095 schools in 2022 for elementary, middle and high school AI education to establish the groundwork for AI education. Korea is operating the 'AI

Education Leading School' program to lead various AI education activities in a flexible and creative educational space that enables the development of various class models for school-based AI education, discovery and spread of best practices, collaboration among students and project learning [11,12]. It is not easy to conduct AI education in schools due to various problems such as understanding of AI functions, insufficient AI infrastructure, convergence education through AI activities and verification of the effectiveness of education. Moreover, since it is difficult to allocate additional education hours due to the lack of SW education time, AI education is being conducted through after-school, creative experience, and club activities [13]. Since various services, textbooks, and teaching aids for AI education are being developed, and various linked activities are being carried out based on the school level, it is necessary to present and verify an AI education program that teachers can introduce through analysis of educational programs and teaching aids practically experienced in elementary schools.

The curriculum for basic AI education is divided into four areas (understanding of AI, principles and applications of AI, data and machine learning, and social impact of AI), and the contents include concepts and characteristics of AI, concepts and roles of intelligent agents, sensor recognition and voice, language understanding, problem solving and exploration, machine learning, deep learning, data mining, and social impact and ethics of AI [14,15,27].

In Korea, various studies, including studies on strengthening teacher's ability for AI education [17,18], studies on the analysis of software and AI contents in elementary schools [19,20], studies on the effectiveness of convergence education using AI for elementary education [21,28], studies on strengthening SW competency of pre-service elementary school teachers and teaching aids [23,24], etc. have been conducted actively.

Looking at the survey on results of AI leading school support research in 2021 [25], teachers in schools responded that the essential competency for AI education operation is 'AI class design competency' followed by the competencies related to 'AI class' and 'AI literacy' such as 'Evaluation competency in AI classes', 'Competency for teaching-learning utilization in AI classes', 'Understanding AI education goals and curriculum', 'Understanding AI literacy', etc.

3. Analysis of AI Education Program in AI Leading School

AI-leading schools operated various programs on AI education and the need for education for teachers, students, and parents and established dedicated AI education spaces (maker space, AI education space, etc.) to promote cooperative classes using various educational tools. For student education, a curriculum (convergence education of regular subjects and existing subjects) for AI education at the school level was developed, and club activities, after-school activities, competitions, visits to related companies, and service application education were conducted for insufficient education and activities. Education research meetings, special lectures by internal and external experts, and teacher competency-strengthening programs were conducted for teacher education. For parent education, opportunities to explain the necessity of AI education were provided through lectures for parents and student presentations.

AI education aims at enhancing educational effectiveness by using the concept and principle of AI and incorporating AI into teaching and learning activities, as well as nurturing talents needed for the future AI society through education on problem-solving skills, knowledge, and social impact to solve problems in real life and various fields. The student activities and educational programs of elementary, middle, and high AI-leading schools to achieve these goals include the following contents:

- Understand the SW and AI (code.org, unplugged CS, unplugged AI)
- Experience the AI program (AutoDraw, QuckDraw, AIVA, ChatGPT, DALL·E2)
- Understand the AI learning process (code.org)
- Experience the AI product (AI camera, AI speaker)
- Participate in cooperative classes (Padlet, Kahoot)
- Learn about AI and ethics, and social impact (code.org, software. kr)
- Learn about various AI technologies applied to surrounding objects by level (Card news, Poster)
- Learn how to process, visualize and recognize data (Word cloud, Naver Papago, CODAP)
- Learn about machine learning and AI program (orange3, Entry, mBlock, App Inventor, ML4Kids, Scratch, Curo AI)
- Create programs using AI technology (AI Chatbot, Python)
- Create programs using AI and Robot (Ozobot, Albert, Neobot, Bit brick, Spike prime, Drone, Microbit, Hamster bot, EV3, TruTru, Makebrick, Pocket Turtle, Artibo)
- Create programs using advanced AI and Arduino (Python, Arduino, KT AI Coding pack)
- Experience AR and VR (3D headset, 360 gear, Oculus quest)
- Make products using 3D pen, 3D printer (3D Scanner, 3D Printer, 123 Design, zSpace XR)

Student education activities of AI-leading schools can be divided into concept understanding and unplugged CS education, AR/VR experience activities, EPL-based SW/AI

education, robot and Arduino application education, and creative maker activities. Although there are differences in programs, robots and activities by school level, the most time was spent on AI experience, EPL, robots, and programming using Arduino.

3.1. Concept understanding of SW·AI and unplugged AI Activities

Coding activities using the code.org site, education of SW and AI concept through cardboard and games designed for unplugged education, the experience of drawings (AutoDraw, QuickDraw) and music service (AIVA) with AI technology applied, and experience of products (AI speaker, AI camera) with AI technology applied were conducted to understand the concept and applications of SW and AI technology. In addition, education was conducted for the activities to create and present card news and posters regarding social changes and ethical issues with the development of AI technology, as well as the concept and brainstorming activities necessary to understand AI technology and implement it in new services. In this process, Padlet(https://ko.padlet.com), Kahoot(https://kahoot.it) and Jamboard(https://jamboard.google.com) services were used as a tool to help communicate and take a quiz test.

3.2. Educational Activities using AR·VR

AR combining real and virtual information, digitized virtual world VR, and MR technology combining virtual information based on real information are used as tools to increase the realism of online interaction and education. Various activities have been carried out to increase educational effectiveness by utilizing realistic content and services through education related to mathematics and three-dimensional figures using VR Math or Circus AR, art and tourist experience education using Google Art & Culture and Expedition, and virtual reality tours of museums and art galleries. In the areas where spatial, three-dimensional, and online interactions are important, Meta Oculus Quest 2, Samsung Gear 360, Sony PlayStation VR2, and Microsoft's HoloLens 2 are used as the effectiveness of AR, VR, and MR technologies increases.

Table 1. Educational tools, functions, and activities for each step of elementary AI education

Step	Description (T: tool, F: function, A: activity)
AI Concept	• (T) code.org (https://code.org), AI unplugged (https://www.aiunplugged.org), Youtube(http://www.youtube.com) • (F) Video, Theory • (A) Understanding AI concepts and contents (machine learning, deep learning), watching videos (AI concepts, AI ethics)
AI Service	• (T) autodraw (https://www.autodraw.com), quickdraw (https://quickdraw.withgoogle.com), AI Speaker (google, kakao, naver, alexa), ChatGPT (https://chat.openai.com), DALL·E2(https://openai.com/dall-e-2/) • (F) Voice recognition, text recognition, image creation, QnA • (A) Using AI technology sites, interactive, QnA, auto code creation, using auto picture creation services, understanding AI application to services
AI Basic Coding	• (T) code.org (https://code.org), AI unplugged (https://www.aiunplugged.org) • (F) AI block program, AI board game • (A)AI for ocean coding, playing board games (unsupervised learning, decision tree, reinforcement learning)
AI Application Coding	• (T) Entry (https://playentry.org), Scratch (https://scratch.mit.edu), ML4Kids(https://machinelearningforkids.co.uk/) • (F) Translation, video detection (face, pose, object), TTS, STT • (A) AI application
AI Model Learning	• (T) Entry (https://playentry.org), ML4Kids+Scratch+Wason Assistant (https://scratch.machinelearningforkids.co.uk/), TeachableMachine(https://teachablemachine.withgoogle.com) • (F) AI model training, classification, recommendation, QnA • (A) AI model learning (supervised learning, unsupervised learning, decision tree) and application, text and image classification, recommendation, QnA, handwriting recognition, emotion classification model learning and application
Data Mining	• (T) Entry (https://playentry.org), Organe3 (https://orangedatamining.com/) • (F) Data processing, table/chart management, data mining/visualization • (A) Understanding data mining and data visualization, data management and chart utilization
AI + Robot/	• (T) Microbit, Lego EV3, Artibo, Ozobot, Spike Prime, Hamster bot • (F) Robot sensor, robot motor/actuator • AI application (classification: image, text, audio) + AI application linked to robot motion

3.3. SW·AI Educational Activities using EPL and Robot

For AI education using EPL and robots, block programs using entry, scratch, mBlock, etc., completed robots (Hamster Bot, Pocket Turtle, Ozobot, Albert) and assembly robots (Neobot, EV3, Bit Brick, Spike Prime, Micro Bit), were used for elementary and middle school students, and AI programming activities using Python and Arduino were conducted for high school students. EPL was typically used for data analysis (Orange 3, Entry) and text and image classification (Entry, ML4Kids, Teachable Machine). Education for AI robot manufacturing and application using sensor data was conducted in the activities linked to Arduino.

3.4. Creative Making Activities

In AI-leading schools, a dedicated space for AI education was built, and maker activities by students were also conducted actively using 3D pens, 3D printers and 3D scanners. In addition, space design, three-dimensional figures, and three-dimensional structure design activities were conducted using 3D production programs (123 design, Sketch up, zSpace XR).

4. Function of AI Educational SW and Tools

As shown in Table 1, EPL and educational tools are widely used in elementary AI-leading schools.

It can be divided into 7 steps of AI concept understanding, AI service, AI basic coding, AI application coding, AI model learning, data mining learning, and AI+robot application in order of educational activities. SW/tools, functions, and activities of each step are shown in table 1.

4.1. Understanding AI Concepts

In the elementary course, educational activities are focused on the necessity of SW and AI education, how to use SW and AI through simple manipulation, and concept understanding and application through various videos or play activities, service applications, coding education, and SW/AI and robot application education. Therefore, basic education on AI concepts, social impact, and ethics of AI development should focus on the following activities. It is important to understand the importance of ethics by discussing various issues that may arise when AI violates ethics.

- Watching videos related to AI concepts using code.org and discussing how AI solves problems.
- Learning AI concepts provided by AI-unplugged textbooks.
- AI education using YouTube, watching related service videos and discussing how AI technology changes society.
- Watching videos related to AI ethics using code.org and discussing ethical issues and importance with the development of technologies.

4.2. Using AI Services

Understanding the current status and development direction of AI applications for industries and services is essential. For this purpose, it is necessary to use AI-applied services and devices. Understanding the basic concept of AI makes it possible to understand the concept and predict the direction of development in the process of experiencing AI application cases. In this process, it is important to feel current technology's limitations and discuss the environment necessary for obtaining better results.

- Drawing pictures through AutoDraw and QuickDraw, using AI services through drawing recognition activities, and discussing applications and limitations of the technology.
- Discussion about the process to understand and process voices through AI speakers (google, kakao, naver, alexa, …), results of use, and impressions of activities.
- QnA through ChatGPT, automatic code creation, using culture creation (poem, novel) functions.
- Using functions such as picture creation, conversion, etc., through the DALL·E2 service.
- Discussion about how AI technologies are developed and applied.

4.3. AI Basic Coding

AI basic coding can be conducted through unplugged education using board games or worksheets or AI application education using block programs, focusing on understanding and utilizing AI functions while minimizing the use of computers or devices. In the case of board games, the effectiveness of education can be increased by proceeding in parallel with education to understand the concept of SW and AI education.

- Block-based image classification programming (AI for ocean) activities using code.org.
- Understanding the AI concept provided by AI unplugged.
- Activities provided by AI unplugged (image classification, making decision tree, reinforcement learning), understanding of the concept and discussion about the results of activities.
- Understanding human-AI confrontation (chess, go, games).

4.4. AI Application Coding

AI application coding is a process of creating application programs using various block coding programs, and existing activities can be converted into AI application activities. It is important to try out various functions through activities, translation, and classification to convert text or

mouse input into voice or motion using entry (translation, voice recognition, video detection), scratch (translation, voice recognition, video detection), ML4Kids (translation, voice recognition, video detection, audio detection, classification, QnA function), etc.

- Understanding translation, voice recognition, and video detection functions of entry or scratch.
- Creating basic programs using AI functions such as input/output substitution, translation, and video detection
- Discussion about the results of AI applications and the services using AI functions.
- Understanding translation, video detection (hand, face, pose), image classification, text classification, audio detection (Spotity) and QnA functions using ML4Kids.
- Creating and presenting various AI application programs
- Discussion about additional functions and services that utilize the additional functions.

4.5. AI Model Learning

In the AI model learning course, it is essential to understand the data processing method, data utilization, model learning process, and utilization of learning results. In particular, it is necessary for students to collect data for learning AI models and to understand that the accuracy of the learned model varies depending on the data.

- Understanding the concept of machine learning.
- Supervised learning of AI models provided by entry or teachable machines: unsupervised learning of images, songs, texts and numbers.
- Programming supervised learning and unsupervised learning using an AI learning model.
- Creating and presenting various application programs using an AI learning model.
- Discussion about AI learning method, data importance, and AI learning models results.

4.6. Data Mining Learning

Data is critical for applications and the accuracy of AI. The activities to understand the importance of data and data mining methods are also very important. The entry provides a function to statistically process data, which can be used for supervised learning and unsupervised learning. Education is needed to understand how data is managed, and AI views data through simple data statistics and chart functions.

- Understanding data management method using entry (table, chart).
- Learning how the AI model processes data.
- Understanding the definition of data, data collection, and data learning process for AI models.
- Understanding the importance of data and the concept of data mining.
- Understanding data statistics and classification using Orange 3 and how to use word cloud, regression model, image classification, etc.

4.7. AI+ Robot Applications

Education linked to robots is required for various input/output and application programs using AI functions. In the elementary course, creative activities are possible through finished robots or the assembly of Lego blocks. It is important to expand the scope of activities by linking AI application functions with robot activities and conducting education in conjunction with maker activities.

- Understanding how to use robots (Artibo, Ozobot, Hamster bot) or assemblable robots (lego EV3, Spike prime), simple sensors and output modules (Micorbit, bit brick), etc.
- Programming linked to AI functions and robots (Linking AI functions with vision, motors and sensors provided by the robot).
- Designing AI functions and robot programming to solve problems assuming various problematic situations.
- Presenting the result of the program using AI and robots and discussing about the limitations of functions and the direction of development

5. Conclusion

The development and introduction of hyper-connected and hyper-converged services are being accelerated with the advancement and application of SW and AI technologies, and the ability to understand and utilize SW and AI is becoming essential for citizens who will live in the future. To this end, SW and AI education in elementary and secondary schools aim at nurturing convergent and creative talents to strengthen the ability to solve problems through computational thinking in various academic and industrial fields.

The purpose of AI-leading schools that started in 2020 to introduce AI education to elementary and secondary schools is to spread AI education, play a role as leading schools in the region, develop AI curriculum and educate teachers, and build infrastructure for AI education. This study reviewed the program status of AI-leading schools and proposed educational activities in elementary schools, focusing on SW and educational tools widely used for AI education. The educational activities include the 7 steps of AI concept understanding, AI service applications, AI basic coding, AI application coding, AI model learning, data mining learning, and AI+robot utilization. Activities in each step and available educational tools were proposed, focusing on a more systematic understanding and utilization of AI education for elementary school students.

To activate AI education in elementary and secondary schools, as mentioned in the AI leading school consulting reports, it is necessary to establish the groundwork for sharing data, AI algorithms and services as an infrastructure for AI education, to support systematic and continuous training to strengthen AI education capabilities, to expand online and offline networking through AI education experts, to secure curriculum and training hours for AI education, and to prepare SW and education tools by steps for AI education. It is also necessary to change the educational paradigm to understand and utilize continuously developing AI technologies in schools.

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