Development of AI Learning Materials Using Physical Computing

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***Abstract*—AI services, including generative AI, have become widespread globally. We are using Artificial Intelligence daily. However, without proper knowledge, users may not achieve the desired results, and there is a risk of inaccuracy. Educational institutions are beginning to establish the groundwork for AI learning. Due to broad learning standards, however, there is few educational materials that cover the fundamental knowledge and skills of using AI. To address this problem, we have developed educational materials that enable basic learning about the mechanisms of AI and motivate learning. For this purpose, we utilize physical computing. This paper reports on the process from the composition of learning standards to the development of educational materials.**

Keywords-AI learning materials; physical computing; learning standards.

I. INTRODUCTION

The proliferation of Artificial Intelligence (AI) services, including generative AI, has made artificial intelligence a familiar presence worldwide. A study conducted by a research group of Massachusetts Institute of Technology involved a task where participants used ChatGPT, one of the generative AIs, to write texts specialized in their areas of expertise. The results showed that the group using ChatGPT reduced the average time required by 40% and increased the quality of output by 18% [1]. In Japan, the Cabinet Office has committed to educational reforms by defining "Mathematics, Data Science, and AI" as the new basics of reading, writing, and arithmetic for the digital society in its AI Strategy 2019 [2]. Acquiring AI literacy is becoming indispensable for thriving in the digital society.

However, there are few examples of educational materials that enable the learning of foundational AI knowledge and skills. We can observe only a few classroom practices in middle school technology and high school industrial arts courses [3] [4]. Consequently, there is a lack of materials that facilitate active learning by students. Furthermore, although practical lessons for acquiring AI literacy are being conducted in primary and secondary education, there is an insufficient learning foundation for instructors.

Thus, this study focuses on developing physical computing educational materials intended for university students who have some experiences with using computers. The rationale for incorporating physical computing is that it has been used as an accessible teaching method for beginners in programming education [5]. Physical computing allows learners to perceive errors through physical movements. By utilizing physical computing materials, the authors have found that students easily acquire of AI literacy.

Section 2 describes related research, Section 3 describes the proposed teaching materials, Section 4 examines the teaching materials, and Section 5 concludes our discussion.

II. RELATED WORK

Scratch is a well-known programming learning material. Scratch is extensible and now it includes materials focused on machine learning. An example is ML2Scratch, which enables image classification using MobileNet through TensorFlow.js [6]. Furthermore, based on this study, researchers have developed another extension that allows for the learning of advanced deep learning techniques such as transfer learning [7].

Google's Teachable Machine is a web-based tool that easily allows to create machine learning models [8]. It supports to create models of three categories, i.e., image, sound, and pose. We can create and export a TensorFlow.js models through collecting learning data directly on the site by taking pictures or recording sounds, and with the press of a training button. A research at the University of Potsdam has shown that utilizing physical computing educational materials promotes not only intrinsic motivation but also creative and constructive learning [9].

Materials using Scratch are web-based, resulting in outcomes being displayed on the screen, akin to the initial experiences of text display in programming learning. Teachable Machine specializes in model creation. While exporting models allows for a broad range of learning opportunities, advancing in applied learning requires prior knowledge of the application areas. A commonality among these materials is their use of transfer learning, which tends to produce relatively accurate results. Although it is easy to obtain results from machine learning through these examples, they do not help for deepening knowledge. We address this problem.

III. SUGGESTED AI LEARNING MATERIALS

In this study, we have carried out the following steps for the development of our educational materials.

1. Establish learning standards for AI literacy based on literatures.
2. Develop physical computing educational materials modeled on autonomous driving, based on the established learning standards.
3. Verify whether the materials can be used for learning.

4. After verification, conduct an evaluation experiment of the proposed materials to assess their effectiveness in improving awareness and knowledge related to AI. (Planned for the future)

A. Developing Learning Standards for AI Literacy

In this study, we have established learning standards necessary for acquiring AI literacy, aiming to experiential learning for everyday use of AI. To define the learning standards, we have investigated models of curricula recommended by consortia dedicated to strengthening education in mathematics, data science, and AI, as well as the G exam, a Japanese certification that tests knowledge of machine learning [10] [11]. This approach ensures that the learning standards cover essential aspects of AI and responsibilities using AI technologies in daily life.

1) Mathematics/Data Science/AI Model Curriculum

We employed the "Mathematics, Data Science, & AI (Literacy Level) Model Curriculum – Cultivating Data Thinking" for setting the AI learning standards [10]. The learning objective of this curriculum is defined as "to proactively acquire the foundational proficiency necessary to proficiently apply mathematics, data science, and AI in daily life, work, and other scenarios." The emphasis is on "the capability to make appropriate, human-centered decisions." The fundamental approach includes "a focus on teaching the 'joy' and 'significance' of engaging with and learning about mathematics, data science, and AI." The curriculum orderly presents learning items and is systematically structured as shown in Table 1. Within this structure, the areas related to AI learning include sections 1-3, 1-4, 1-5, 1-6, and 3-1.

In the first section, "Utilization of Data & AI in Society," the focus is mainly on AI knowledge and application, presenting skill sets for specialized AI and general-purpose AI, among others. The second section "Data Literacy" discusses how to handle data, but it hardly mentions AI, hence we do not focus on this study. The third section, "Considerations in the Utilization of Data & AI," suggests covering negative examples of AI utilization and data ethics, among other topics.

TABLE I. STRUCTURE OF AI LITERACY LEVEL MODEL CURRICULUM

1. Introduction ***Utilization of data and AI in society***	1-1 Changes occurring in society
	1-2 Data used in society
	1-3 Application areas of data and AI
	1-4 Technology for data/AI utilization
	1-5 Fields of data/AI utilization
	1-6 Latest trends in data and AI utilization
2. Basic ***Data literacy***	2-1 Read the data
	2-2 Explain the data
	2-3 How to use data
3. Knowledge Considerations in the Utilization of Data & AI	3-1 Points to note when handling data and AI
	3-2 Points to note when protecting data

2) DLA Deep Learning For GENERAL

In order to survey the required knowledge of machine learning, we investigated the official textbook for the Deep Learning G Certification, "Deep Learning G Certification Official Textbook 2nd Edition," which is structured according to the syllabus of the qualification examination. The official textbook is comprised of seven chapters, with contents as follows:

1. What is Artificial Intelligence (AI)?
2. Trends Surrounding Artificial Intelligence.
3. Issues in the Field of Artificial Intelligence.
4. Specific Methods of Machine Learning.
5. Overview of Deep Learning.
6. Methods of Deep Learning.
7. Toward the Social Implementation of Deep Learning.

We have focused on Chapters 1, 2, and 7. Chapter 1 discusses the nature of AI, including its history and classification, and explains the differences between machine learning and deep learning at various levels. Chapter 2 addresses the trends in AI, emphasizing the history and relationship of machine learning and deep learning research. It particularly notes that desirable results can be achieved through accumulating data in machine learning and explains the mechanisms of machine learning and deep learning differ, and how they are different. Chapter 7 covers methods and considerations for utilizing AI towards social implementation. The chapter also discusses how to handle data, including the quality of datasets. It emphasizes how to eliminate bias, and how to process and to analyze data fairly, and how to learn regularity from data.

Based on the observation of Chapters 1 and 2, we have formulated the foundational learning criteria and perspectives on AI, which are presented in Table 2.

TABLE II. FOUNDATIONAL LEARNING CRITERIA AND PERSPECTIVES ON AI

	Learning Criteria & Perspectives	***Points of Understanding***
A	Generality & Specificity	Specializes in performing certain tasks (e.g., image & voice recognition)
B	Learning & Training Data	The operation of AI is indispensable for learning data, with the quality and quantity of data being crucial
C	Validity of Inference Results	The quantity and quality of training data can affect achieving the desired results

The rationales for formulating each perspective are as follows:

A. From the perspective of "human-centered" importance in mathematics, data science, and AI, it is necessary to learn about what AI can and cannot do.

B. As handled in prior research and teaching practices, approaches to collecting learning data for image recognition, the emphasis on the consciousness of statistical work for data utilization in mathematics, data science, and AI, and the G Certification's point on the necessity of processing, analyzing, and learning the training data for AI's social implementation are reasons for this perspective.

C. The G Certification mentions that desirable results can be achieved depending on the quantity and quality of data, underlining the necessity to understand that the desired outcomes may not always be attainable depending on the data.

B. *Physical Computing Teaching Materials*

We developed educational materials for experiential physical computing that allow students for comprehensive learning of the established learning criteria and perspectives. The goal of these materials is to motivate AI learning and enable active learning.

1) *Specifications of the Educational Material*

In this research, we developed a mobile robot-like educational material that can recognize signs through image recognition using the Jetson Nano B01, a single-board computer for AI learning released by NVIDIA [12]. It controls the robot according to the meaning of the signs. Figure 1 shows the developed robot-like educational material, Figure 2 shows the hardware configuration. The robot-like educational material communicates with the server using wireless network so that it executes the AI learning model.

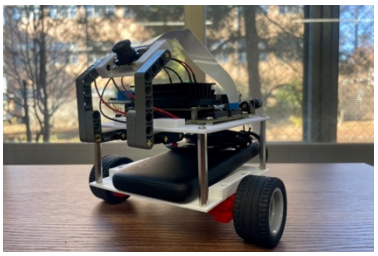

Figure 1. Developed physical computing teaching materials.

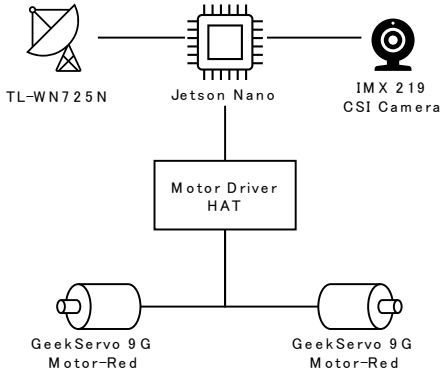

Figure 2. Hardware configuration diagram.

The software configuration is as follows. We employed the JetPack 4.6 platform for Jetson, published by NVIDIA, and Docker containers used by the NVIDIA Deep Learning Institute. They allow operators to access Jupyter Lab via a browser. Additionally, we used pre-installed PyTorch, which is the machine learning library used in this container.

2) *Overview of the Robot-like Educational Material*

This robot-like educational material recognizes signs and proceeds according to the meaning of those signs through image classification using Convolutional Neural Networks (CNN). The material developed for this occasion classifies two classes (background and signs). We conducted experiments utilizing a sign indicating a speed limit of 10 km/h to slow down the operational speed of the material. Additionally, as an advanced application, there is a program that classifies six classes. Table 3 shows the recognized objects and corresponding actions.

TABLE III. CORRESPONDENCE TABLE OF RECOGNIZED OBJECTS AND ACTIONS

Recognition Objects	***Actions***
Background	Normal operation
Speed limit 10km	Operating speed 10
Speed limit 30km	Operating speed 30
Stop	Pause (1 second)
No entry	allowed End of operation
People	Stop until no more people are classified

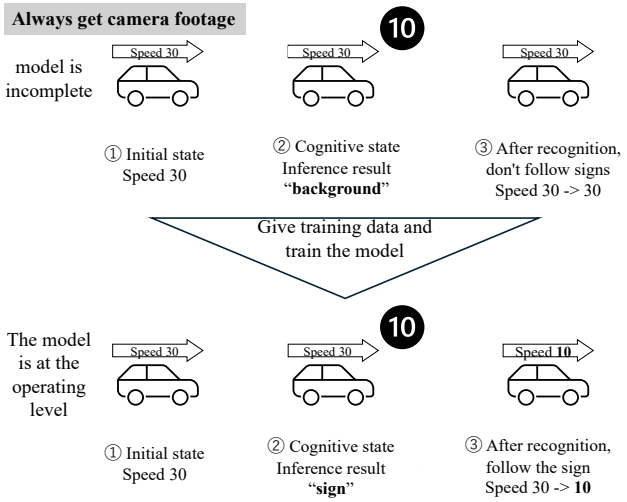

Figure 3. Operational Image of the Educational Materials.

Figure 3 shows the conceptual image of the operations of the robot-like educational material.

IV. VERIFICATION OF EDUCATIONAL MATERIALS

Learners can perform a series of AI learning activities by accessing Jupyter Lab via a browser. He or she must perform the following procedures.

1. Prepare the learning data.
2. Define the model.
3. Train the model.
4. Test the model.
5. Adjust the data according to the results.

First, the learner performs the step 1 through 4. Of course, the robot-like educational material cannot classify signs, and executes incorrect actions. Then, the learner proceeds to step 5 to adjust training data and the frequency of training sessions. Then he or she iterates the procedure steps 3, 4 and

5 until the robot-like educational material achieves the accurate inference. Figure 4 shows the experiments of this procedure.

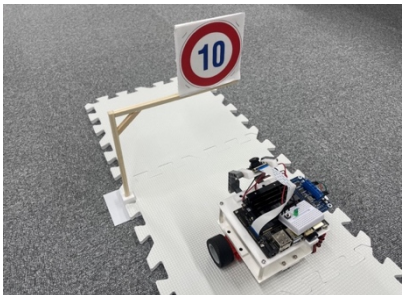

Figure 4. Operational Aspect of the Proposed Educational Material.

In step 3, the robot-like educational material collects learning data through a camera mounted on it.

For step 5, adjusting the training data, learners individually modify the learning data and model training. Adjusting the learning data involves increasing the data volume based on the operational results. For the model training, we increase the number of learning iterations until the loss is stabilized, since the system presents the number of epochs and the loss graph. After adjustments, learners check the accuracy of the model through the operation of the robot-like educational material. Figure 5 shows the control panel of the system. The learners can adjust the data and learning.

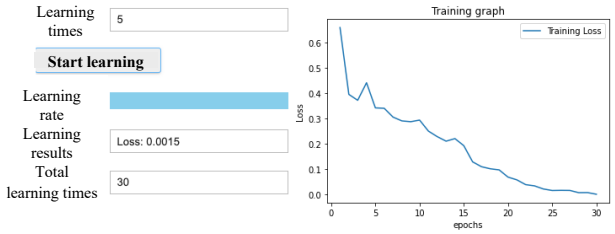

Figure 5. Adjustment of Model Training.

This teaching material is built based on the official PyTorch tutorial. Learners can observe how the model training progresses using the control panel shown in Figure 5 without programming.

The proposed educational materials incorporate image recognition. We must investigate whether the learners can comprehend the learning standards through the experiences of image recognition learners. We made learners engage in an AI experience focused on character recognition (image recognition) aligned with the learning standards to assess their adequacy.

TABLE IV. VALIDITY OF LEARNING CRITERIA FOR IMAGE RECOGNITION N=3

Learning Criteria	*Understood*	*Not Understood*
A	3	0
B	2	1
C	3	0

Following this experience, Table 4 shows the collected responses on the comprehensibility of each learning standard. We have confirmed that the learners deeply comprehend the learning standards we proposed by studying image recognition.

V. CONCLUSION AND FUTURE WORK

We have investigated learning standards for acquiring AI literacy and have created robot-like educational materials to help learners to comprehend the machine learning based on these standards. The validation of these learning standards revealed that learners enhanced their understanding of AI literacy through image recognition. Future efforts will focus on conducting evaluation experiments to assess the educational impact of the proposed materials.

ACKNOWLEDGMENT

This work was partially supported by JSPS KAKENHI, Grant Number JP24K06237.

Yasushi Kambayashi gave us useful comments. We appreciate them very much.

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