Evaluation of AI Learning Materials Using Physical Computing

Toshiyasu Kato
Department of Information and Media Engineering
Nippon Institute of Technology
Minamisaitama-gun - Saitama, Japan
email: katoto@nit.ac.jp

Yuto Chino
Department of Technology
Fuchu City Fuchu 6th Junior High School
Fuchu - Tokyo, Japan
email: edu.yutochino@gmail.com

***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. Furthermore, an experiment to evaluate the effectiveness was conducted.**

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

I. INTRODUCTION

This paper is an extension of work originally presented in The First International Conference on IoT-AI 2024 (IARIA) [1].

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% [2]. 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 [3]. 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 [4] [5]. 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 [1]. We named this the "AI Builder Learning Kit". The rationale for incorporating physical computing is that it has been used as an accessible teaching method for beginners in programming education [6]. Physical computing allows students to perceive errors through physical movements. By utilizing physical computing materials, the authors have found that students easily acquire of AI literacy. In the evaluation experiment, students will study using the developed teaching materials and verify the effectiveness of the materials by comparing them with learning using textbooks alone.

II. SUGGESTED AI LEARNING MATERIALS “AI BUILDER LEARNING KIT “

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 [7] [8]. This approach ensures that the learning standards cover essential aspects of AI and responsibilities using AI technologies in daily life.

The reference literature [7] for this material is based on the "AI Strategy 2019" established by the Japanese government in 2019. Therefore, this material follows Japan's traditional educational methods.

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 [7]. 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 I. 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.

The mathematical, data science, and AI (literacy level) curriculum explicitly focuses on data science, primarily statistics, with AI employed as a means within this context. The fundamental approach emphasizes the 'fun' and 'significance' of learning, which motivates students to engage actively and enjoyably with AI.

From the 'G certification' perspective, the curriculum is based on statistical operations that can be learned in mathematics, data science, and AI, highlighting how AI can be utilized in the real world. It includes understanding what AI is, its mechanisms, and foundational knowledge, while also emphasizing the importance of 'how data can be applied.' The recurrent themes of data quantity and quality are considered the most crucial knowledge for learning AI.

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 II.

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. As shown in Figure 2, the teaching materials and PCs are connected via Wi-Fi. Students learn machine learning while checking the camera input on the PC.

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 [9]. 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.

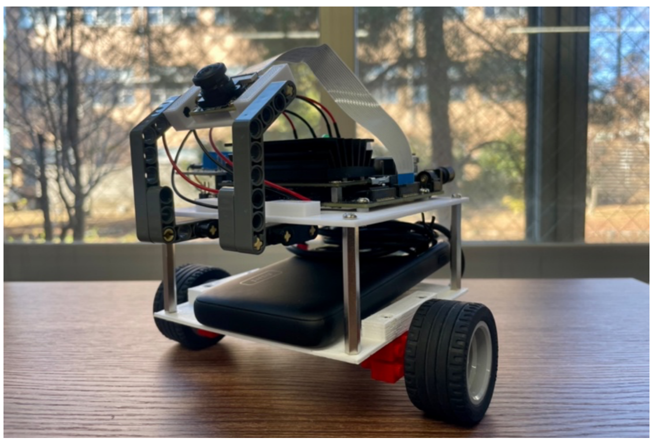

Figure 1. Developed physical computing teaching materials.

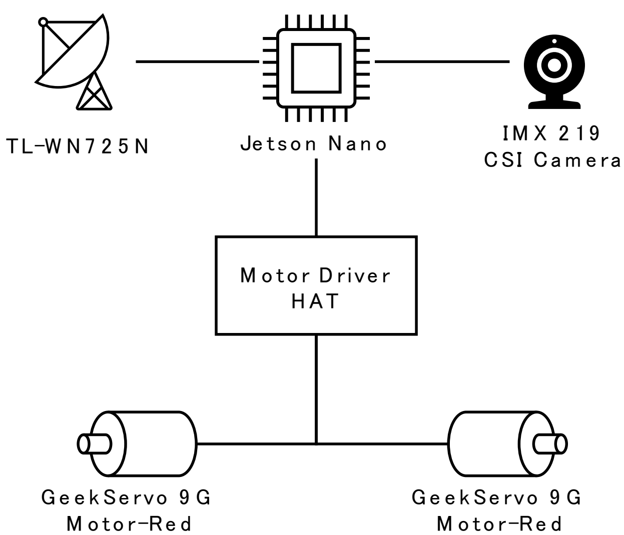

Figure 2. Hardware configuration diagram.

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.

The specifications of the educational materials are shown in Table III, and the components of the materials are listed in Table IV.

TABLE III. SPECIFICATIONS OF THE DEVELOPED EDUCATIONAL MATERIALS

Specification	***Details***
Dimensions	170mm (W) x 110mm (D) x 150mm (H)
Power Source	Lithium-ion battery
Continuous Operation Time	4 hours
Charging Method	USB charging via USB Type-C

TABLE IV. LIST OF COMPONENTS FOR THE EDUCATIONAL MATERIALS

Category	***Component Name***	***Quantity***
Controller	Jetson Nano B01	1
Drive Motor	GeekServo 9G Motor-Red	2
Motor Driver I2C Interface	WaveShare 15364 Motor Driver HAT for Raspberry Pi	1
Camera	Yahboom IMX219 160-degree CSI Camera	1
Wi-Fi Module	TP-Link TL-WN725N	1
Battery	INIU POWERBANK BI-B6	1
Tires	LEGO 4184286	2
Wheels	LEGO 4297210	2
Caster	TAMIYA No. 144 Ball Caster	1

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 V shows the recognized objects and corresponding actions.

TABLE V. 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

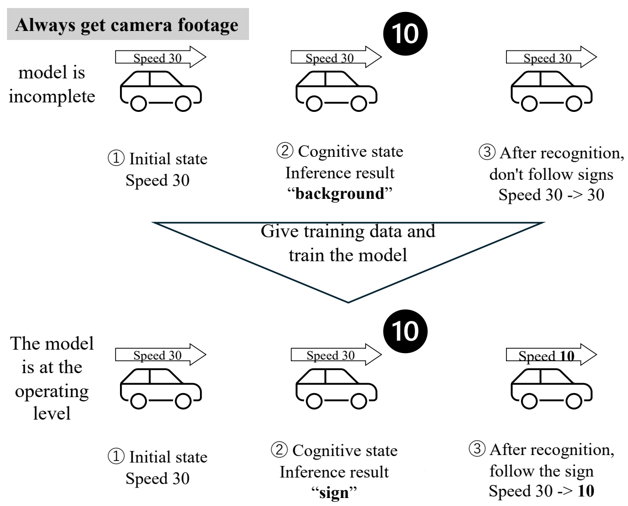

Figure 3. Operational image of the educational materials.

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

The educational materials are structured around five processes based on the perspectives shown in Table I. By sequentially implementing these processes, students can experience and study image classification AI. The established processes and the corresponding learnable perspectives they cover are shown in Table VI.

TABLE VI. LEARNING PROCESSES AND PERSPECTIVES IN THE EDUCATIONAL MATERIALS

Step	***Content***	***Perspective***
1	Prepare the learning data	B
2	Define the model	A
3	Train the model	B
4	Test the model	C
5	Adjust the data based on results	B

III. VERIFICATION OF EDUCATIONAL MATERIALS

Students can perform a series of AI learning activities by accessing Jupyter Lab via a browser. He or she must follow the steps in Table VI.

First, the student performs the step 1 through 4. Of course, the robot-like educational material cannot classify signs and executes incorrect actions. Then, the student 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 and 5 shows the experiments of this procedure.

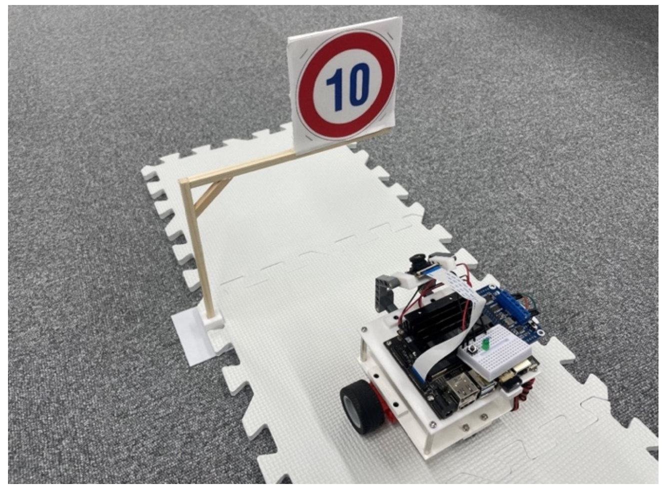

Figure 4. Operational aspect of the proposed educational material.

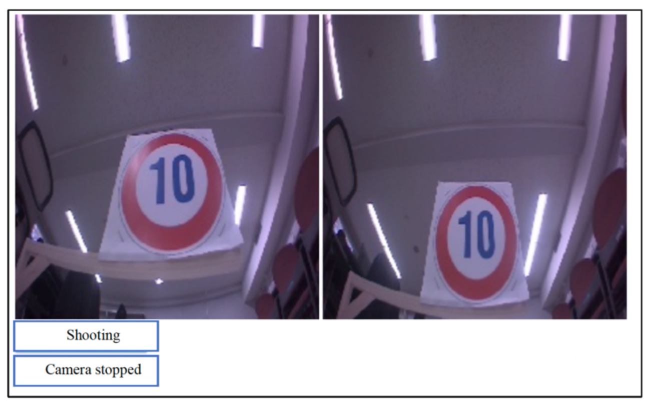

Figure 5. Learning data collection screen.

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

For step 5, adjusting the training data, students 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, students check the accuracy of the model through the operation of the robot-like educational material. Figure 6 shows the control panel of the system. The students can adjust the data and learning.

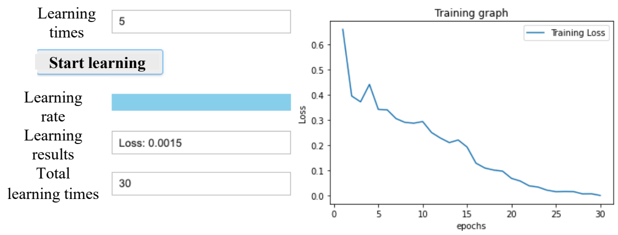

Figure 6. Adjustment of model training.

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

A. Verification of Learning Standards

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

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

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

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

B. Supplementary Textual Educational Materials

To supplement the knowledge that cannot be fully covered through the learning flow and experience of the developed educational materials, a roadmap-style text-based educational resource was created. Additionally, for the evaluation experiment, a web application was developed that displays the text and records the viewing time for each page.

In this study, two different types of text-based educational materials were developed for the evaluation experiment. The first is a text that serves as a guideline for using the physical computing materials. The second is a standalone text that allows students to complete their studies without using physical computing materials.

The text-based educational material consists of 19 pages, divided into two parts. The first part explains the basic knowledge based on the G certification. The second part provides a roadmap for experiential learning using the physical computing materials. Table VIII shows the correspondence between the content of each page of the text-based material for using the physical computing materials and the relevant perspectives.

TABLE VIII. CONTENT AND PERSPECTIVES OF THE PHYSICAL COMPUTING-BASED TEXT EDUCATIONAL MATERIAL

Page	*Content*	*Perspective*
1, 2, 7	Cover, Section Cover Pages	-
3	What is AI?	A, B, C
4	AI Excels at Specific Tasks	A
5	AI Learning Process	B
6	The Four Levels of AI	A, C
8, 9	Introduction of the Materials, Learning Objectives, Device Operation	-
10	Executing the Setup Program Cells	-
11	How to Capture Learning Data	B
12	Preparing Learning Data (Data Limitations)	B
13	Defining the AI Model	-
14	Model Training (Specifying Number of Iterations), First Round	B
15	Verifying Operation, First Round	B, C
16	Model Training (Removing Iteration Limitations), Second Round	B
17	Verifying Operation, Second Round	A, C
18	Enriching Learning Data, Model Training	B
19	Verifying Operation, Third Round	A, C

When using educational materials in Jupyter Lab, it is important to ensure that students can follow textual instructions and terminology to accurately execute operations. Each page of the text contains themes to be learned and the content of the cells to be executed.

Furthermore, an application has been developed using PHP and JavaScript to record the viewing time of each text page and the execution time of each cell, viewable as images online. The application allows users to switch between text pages using 'Next' and 'Back' buttons, capturing the time spent on each page. The 'I have learned and executed' button records the time from when the page is displayed to when the button is pressed. The application for viewing the text is shown in Figure 7. The top of Figure 7 contains a bar graph that allows users to check their learning progress, the center contains a text display area, and the bottom contains an operation area.

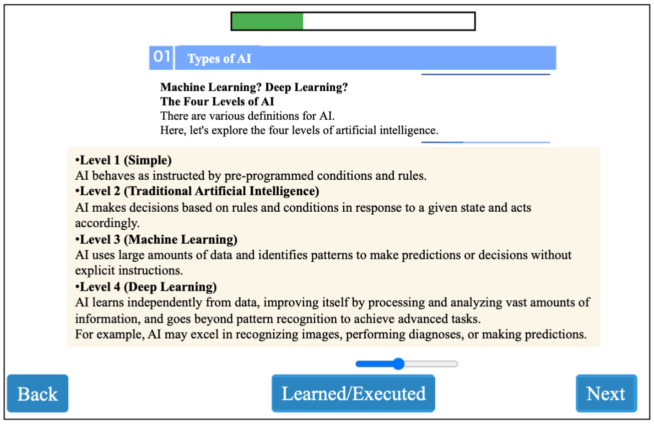

Figure 7. Application for viewing textbooks

IV. EVALUATION EXPERIMENT

To verify whether the established learning standards could be met through learning with physical computing materials, an evaluation experiment was conducted with 17 university science students, divided into an experimental group (8 students) and a control group (9 students).

A. Experimental Procedure

The evaluation experiment proceeded as follows:

1. Conduct a preliminary survey titled "Survey on Awareness about AI" (hereafter referred to as the "Awareness Survey") with the 17 participants.
2. The control group worked on materials based on the official PyTorch tutorials corresponding to section 3.B of the text, while the experimental group used physical computing materials along with the text from section 3.B.
3. Conduct a post-survey titled "Knowledge Survey about AI" (hereafter referred to as the "Knowledge Survey").

The Awareness Survey, designed based on prior studies and practices related to AI awareness, aims to determine if the educational materials effectively motivate and enhance awareness. The items of the Awareness Survey are listed in Table IX. The evaluation scale for Question 4 consists of four levels: 1. Don't know, 2. Have heard of it, 3. Know it, and 4. Can explain it.

The Knowledge Survey checks whether participants understand each item based on learning standards and perspectives, with questions set from knowledge and application skills necessary for G certification and learning standards. The items of the Knowledge Survey are shown in Table X. The correct answer criteria for Question 5 are met when the steps are presented in the following order: 1. Prepare the data, 2. Build the model, 3. Train the model, and 4. Test and verify the completed model.

TABLE IX. AWARENESS SURVEY ITEMS

No.	*Item*	*Collection/Evaluation Method*
1	Choose the closest representation of your future vision of AI	Four-point scale
2	How do you feel about the improvement of life with AI development?	Four-point scale
3	What are your feelings towards AI?	Four-point scale
4	Choose the description that best matches your understanding of AI	Four-point scale
4-1	How is AI created?	
4-2	Why can AI recognize images or generate text?	
4-3	What can AI do?	
4-4	The difference between AI and robots	

TABLE X. KNOWLEDGE SURVEY ITEMS

No.	*Item*	*Collection/Evaluation Method*
1	Choose the closest term related to AI from the options provided	Four-point scale
1-1	Machine learning	
1-2	Deep learning	
1-3	Dataset	
1-4	Image recognition	
2	Select whether AI can perform the following tasks	True/False
2-1	Recognize a face and identify the individual	
2-2	Diagnose diseases accurately	
2-3	Determine the cause of a machine breakdown	
2-4	Explain information about an event that occurred yesterday	
3	Select all correct processes necessary for developing an image recognition AI model	True/False
4	Given a dog image was classified as a cat despite sufficient training, what is the most likely cause, assuming correct classification of other dogs?	True/False
5	Rearrange the steps to create an AI	True/False

B. Experimental Results

The effectiveness of enhancing awareness was evaluated by comparing the changes in the Awareness Survey results before and after the experiment using a two-tailed t-test. The results are shown in Table XI.

TABLE XI. RESULTS OF THE AWARENESS SURVEY BEFORE AND AFTER IMPLEMENTING EDUCATIONAL MATERIALS

Survey Item	***Pre-Survey***		***Post-Survey***		***t-test***	
	M	***SD***	***M***	***SD***	***t-value***	
Vision of AI	4.00	0	4.00	0		n.s.
Support for AI Development	3.63	0.48	3.63	0.48		n.s.
Support for AI Utilization	3.50	0.50	3.88	0.33	-2.05	n.s.
Understanding of AI Mechanisms	2.00	0.71	2.88	0.33	-2.97	*
Principles of AI	1.88	0.78	3.25	0.43	-4.25	**
Applications of AI	2.75	0.83	3.38	0.48	-2.38	*
AI vs. Robots	2.13	0.93	3.13	0.60	-3.06	*

n=8, *: p <.05, **: p <.01

Improvements were observed in most survey items, except those already had high evaluations before the implementation. Notably, the understanding of AI principles significantly increased, as indicated by the statistics (t (7) = -4.25, p <.01). This suggests that the educational materials effectively enhanced comprehension of AI principles.

Next, to verify the validity of the materials, the knowledge survey checked terminology on a four-point scale, while other items were scored as 1 for correct and 0 for incorrect answers. Changes between the experimental and control groups were evaluated using a two-tailed t-test. The results are shown in Table XII.

TABLE XII. RESULTS OF THE KNOWLEDGE SURVEY AFTER IMPLEMENTING EDUCATIONAL MATERIALS

Quiz Category	***Experimental Group n=8***		***Control Group n=9***		***t-test***	
	M	***SD***	***M***	***SD***	***t-value***	
Terminology	3.16	0.51	3.53	0.55	-2.85	**
Applications of AI	0.84	0.36	0.58	0.49	2.46	*
Applied Problems	0.69	0.46	0.50	0.50	1.10	n.s.
Procedures Overall	0.50	0.50	0.67	0.47	-0.66	n.s.
Correct Answer Rate	0.75	0.12	0.52	0.21	2.89	*

*: p <.05, **: p <.01

In the terminology section, the control group tended to score higher. However, the experimental group showed higher average scores in practical applications, and although no significant difference was found in application problems, the correct answer rate was higher. Since significant differences were observed in problem-solving rates, the educational materials are considered effective for enhancing practical AI knowledge and as introductory materials for AI learning.

V. 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 [10]. Furthermore, based on this study, researchers have developed another extension that allows for the learning of advanced deep learning techniques such as transfer learning [11].

Google's Teachable Machine is a web-based tool that easily allows to create machine learning models [12]. 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 [13].

Felix Hu and colleagues developed a tangible programming game called "Strawbies" for children aged 5 to 10 years [14]. The game involves programming with wooden tiles, which are not square but specially shaped to prevent incorrect connections. Although this design reduces the freedom of programming, it offers the benefit of allowing users to intuitively understand whether a connection is possible or not. Aditya Mehrotra and his team implemented robot programming classes where students rearranged printed program blocks, and they evaluated several methods [15]. However, the purpose of their study was to evaluate the methods themselves, and they did not adjust the instructional content in real-time based on students' progress to ensure knowledge retention. Kato and others developed and evaluated a system that collects and analyzes students' programming progress, providing this information to assist instructors in efficiently guiding students [16]. However, since this analysis focuses on programming languages, it cannot be directly applied to tangible educational materials.

Regarding these studies, 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.

Table XIII shows the previous cases and the characteristics of the authors.

TABLE XIII. COMPARISON WITH OTHER STUDIES

Name	*Physical Computing*	*AI Learning*	*Multi-Student*	*Analysis on Class*	*Analysis after Class*
AI Builder Learning Kit	+	+			+
ML2Scratch [10]		+	+		
Teachable Machine [12]		+	+		
Strawbies [14]	+				
PaPL [15]	+		+		+
Katos' System [16]			+	+	+

VI. CONCLUSION AND FUTURE WORK

In this study, we established fundamental learning standards and perspectives for learning the basic mechanisms of AI and developed educational materials that align with these standards. As a result, students' awareness of various aspects of AI improved, and their understanding of its mechanisms and principles increased. These outcomes suggest that the developed materials can enhance both the understanding of basic AI mechanisms and literacy in AI-related awareness.

Future challenges include making it easier to learn terminology that was not fully covered by the current materials and improving the materials to incorporate generative technologies rather than just classification.

ACKNOWLEDGMENT

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

REFERENCES

[1] T. Kato and Y. Chino, “Development of AI learning materials using physical computing,” The First International Conference on IoT-AI, IARIA, 2024.

[2] S. Noy and W. Zhang, “Experimental evidence on the productivity effects of generative artificial intelligence,” Science 381.6654: pp. 187–192, 2023.

[3] Cabinet Office: AI Strategy 2019. [Online]. Available from: https://www8.cao.go.jp/cstp/ai/aistratagy2019.pdf 2023.12.23

[4] N. Takezawa, T. Yamamoto and H. Koura, "Proposal and Evaluation of a Teaching Process for Learning Image Recognition Technology Using Artificial Intelligence through Programming," Japan Society of Educational Information, vol. 38, no. 1, pp. 37–48, 2022.

[5] N. Mukaida, "Examination of Classes to Think About How to Face AI in AI Literacy Education," Japan Educational Research Society of the AI era, vol. 5, pp. 9–15, 2022.

[6] P. Mareen and R. Ralf, “Impact of Physical Computing on Learner Motivation,” Koli Calling '18, pp. 1–10, 2018.

[7] Consortium for Strengthening Mathematics and Data Science Education in Japan, "Mathematics/Data Science/AI (Literacy Level) Model Curriculum -Cultivating Data Thinking-, " [Online]. Available from: http://www.mi.u-tokyo.ac.jp/consortium/pdf/model_literacy.pdf 2024.01.04

[8] Japan Deep Learning Association, "Deep Learning G Test Official Text, " 2nd edition, 403p, 2021.

[9] NVIDIA, "Jetson Nano developer kit, " [Online]. Available from: https://www.nvidia.com/ja-jp/autonomous-machines/embedded-systems/jetson-nano-developer-kit/ 2024.01.04

[10] J. Ishihara, "Introducing an extension that makes machine learning available from Scratch," Interface, vol. 47, no. 5, CQ Publishing, pp. 148-152, 2021.

[11] T. Yagi and T. Yamaguchi, "Building a machine learning experience system for beginners using Scratch, " Bulletin of Edogawa University, vol. 30, pp. 473-485, 2020.

[12] Google: Teachable Machine [Online]. Available from: https://teachablemachine.withgoogle.com/ 2024.01.17

[13] M. Przybylla and R. Romeike, “Impact of Physical Computing on Learner Motivation, ” Koli Calling 2018, pp. 1-10, 2018.

[14] F. Hu, A. Zekelman, M. Horn and F. Judd, “Strawbies: explorations in tangible programming,” IDC '15: Proceedings of the 14th International Conference on Interaction Design and Children, pp. 410-413, Boston Massachusetts, United States of America, June, 2015.

[15] A. Mehrotra, C. Giang, N. Duruz, J. Dedelley, A. Mussati, M. Skweres and F. Mondada, “Introducing a Paper-Based Programming Language for Computing Education in Classrooms,” ITiCSE '20: Proceedings of the 2020 ACM Conference on Innovation and Technology in Computer Science Education, pp. 180-186, New York, United States of America, June, 2020.

[16] T. Kato, Y. Kambayashi, Y. Terawaki and Y. Kodama, “Estimating Grades from Students' Behaviors in Programming Exercises Using Deep Learning,” International Conference on Computational Science and Computational Intelligence (CSCI), pp. 1115-1119, IEEE, 2017.